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The National Science Foundation is an independent agency of the United States Government, established for the support and encouragement of basic research and education in the sciences and for the development of national science policy. It has just concluded its first decade of operations. This article discusses the principal programmes of the foundation and its relations with the universities, the scientific community, and with other federal agencies operating in fields of science and technology.

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Of all the scourges that man has to face, insect pests are among the most serious. They can cause untold damage to crops and some of them transmit diseases affecting millions of people.

The problems confronting agricultural specialists and public health officers are becoming increasingly complicated as new methods of pest control are developed.

Early control methods were elementary and not very efficient, but, in recent years, the struggle against pests has made great strides as a result of the widespread introduction of synthetic organic insecticides. But though these compounds have many undeniable advantages, they also have drawbacks which must not be underestimated. For this reason, a tremendous effort has been made over the last decade in laboratories throughout the world to devise effective methods of biological control.

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THE NATIONAL SCIENCE FOUNDATION

by

ALAN WATERMAN

Dr. Alan T. Waterman was appointed Director of the National Science Foundation by the President of the United States on 6 April 1951.

He graduated A.B. at Princeton University in 1913 and received the degree of Ph.D. in Physics from Princeton in 1916.

Dr. Waterman has conducted research on the conduction of electricity through solids; thermionic, photoelectric emission and allied effects; and electrical properties of solids.

He is a member of various government scientific research bodies including the Federal Council for Science and Technology. He is also a Fellow of the AAAS and of numerous other research societies.

INTRODUCTION

The Government of the United States has a long tradition of interest in scientific research and development. In the beginning these activities centred largely on the collection and analysis of data relating to agriculture and commerce. Later the government began to engage directly in research relating primarily to agricultural and commercial problems and to national defence. Among the first agencies established for such purposes were the United States Naval Observatory, the Coast and Geodetic Survey, the Army's Topographical Engineers, the Navy's Hydrographic Office, the Weather Bureau, and the United States Department of Agriculture. Early research by the government was conducted in its own laboratories.

Between the first and second world wars, the government's scientific activities were expanded to include aeronautical research (under the National Advisory Committee for Aeronautics) and a broad programme of medical research (under the United States Public Health Service). The social sciences were brought to bear on a variety of problems, principally by the Departments of Commerce, Labor, and Agriculture.

The National Academy of Sciences, established by Congress during the Civil War, and the National Research Council, similarly set up during World War I, are quasi-governmental bodies serving in an advisory capacity upon request.

Until very recently, all the government's scientific activities were applied in nature—that is, they were directed toward the solution of specific problems. The idea of fostering and encouraging basic research for its own sake, and of supporting such research with government funds, did not arise until World War II. Toward the end of the war, when thoughts were once more turned to the future and plans for rebuilding and restoring began to be uppermost,

the importance of basic research began to be increasingly evident. It was also obvious that scientific manpower was a very important national resource—so much so that the education and training of scientists could no longer be left to chance.

A great deal of thought was being given to these matters by the scientists who had been engaged in the wartime research effort. They were deeply aware, for example, of the extent of American dependence on European basic research and they were concerned as to the effects the disruption of laboratories in Europe would have on world-wide scientific progress. They crystallized their thinking and their recommendations in a report, *Science, the Endless Frontier*, written in response to a letter that had been addressed by President Franklin D. Roosevelt, in 1944, to Vannevar Bush, head of the Office of Scientific Research and Development. The President wanted to know how the lessons that had been learned from the wartime research experience could be applied in the days of peace that lay ahead. Dr. Bush, backed by the studies and advice of eminent scientists and educators, replied that in his judgement the national interest in scientific research and scientific education could best be promoted by the creation of a national science foundation. The purpose of such a foundation would be to develop and promote a national policy for scientific research and scientific education, to support basic research in non-profit organizations, to develop scientific talent in American youth by means of scholarships and fellowships.

Science, the Endless Frontier strongly emphasized the importance of basic research: 'Basic research leads to new knowledge. It provides scientific capital. It creates the fund from which the practical applications of knowledge must be drawn. . . . Today, it is truer than ever that basic research is the pacemaker of technological progress. . . . A nation which depends upon others for its new basic scientific knowledge will be slow in its industrial progress and weak in its competitive position in world trade, regardless of its mechanical skill.'

Dr. Bush viewed the publicly and privately supported colleges and universities and the endowed research institutes as the centres of basic research that must furnish both the new scientific knowledge and the trained research workers. He pointed out that if they were to meet the rapidly increasing demands of industry and government for new scientific knowledge, their basic research would have to be strengthened by the use of public funds.

Basic research is fundamental to all the research and training needs which the report considers. It is through basic research in biology, biochemistry and other sciences, for example, that the solutions to major disease problems are to be reached. Basic research in necessary to national defence. Economic growth and the development of new products in industry are dependent upon rich resources of basic knowledge. And finally, knowledge of the methods and techniques of basic research is essential to the training and full development of skilled research investigators.

Although the importance of a national science foundation now seems obvious, its establishment by the Congress was by no means perfunctory. Five years of legislative debate over the structure of the proposed foundation ensued before the National Science Foundation Act of 1950 brought the new agency into being.

ORGANIZATION OF THE NATIONAL SCIENCE FOUNDATION

Most of 1950 was occupied in the selection and appointment of the 24 members of the National Science Board who, as specified by the law, are persons 'eminent in the fields of the basic sciences—medical science, engineering, agriculture, education, or public affairs'. The members are selected solely on the basis of established records of distinguished service and are so selected 'as to provide representation of the views of scientific leaders in all areas of the nation'. The law prescribes that, in addition to the board, there shall be a director, also appointed by the President, and divisional committees for each division of the foundation. At the present time the divisions of the foundation are: Biological and Medical Science; Mathematical, Physical, and Engineering Sciences; Scientific Personnel and Education; and Social Sciences.

As the functions of the foundation have grown and expanded, the following offices have been added: the Office of Special Studies, for the collection and analysis of data relating to the national research and development effort; the Office of Special International Programs, which co-ordinates such activities as the Antarctic programme, foreign science education programmes, and various scientific activities of an international character in which scientists in the United States have an interest or play a part; the Office of Institutional Programs, which administers uncommitted grants to institutions and grants for laboratory renovation and equipment; the Office of Scientific Information Service, which supports research on new and improved methods for the storage, retrieval and dissemination of scientific information and which also acts as a co-ordinating centre for scientific and technical information services of the Federal Government, and is responsible for promoting closer co-operation between scientific information services within and outside the government.

The foundation actually began operations with the appointment of the director on 6 April 1951. It has thus been operating for a full decade, and it is possible in retrospect to observe certain trends in its growth and development.

Although the National Science Foundation was established along organizational lines typical of the major private foundations, it differs in one important respect, and that is in its funding. Private foundations, in addition to being supported by private funds, also have the advantage of capital endowments for extended periods of time. The National Science Foundation, in common with all other agencies and departments of the Federal Government, receives

its appropriations from the Congress on an annual basis. During the first years of its existence, the Foundation's appropriations were exceedingly modest, ranging from $3.5 million for its first year of operations, fiscal year 1952, to $16 million for fiscal year 1956. The following year, fiscal year 1957, the foundation's budget was more than doubled, with an appropriation of $40 million; and since that time, there have been steady increments. The appropriation for fiscal year 1961 was $175.8 million.

The principal functions of the foundation are:

To develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences;

To initiate and support basic scientific research and programmes to strengthen scientific research potential in the mathematical, physical, medical, biological, engineering, and other sciences, by making contracts or other arrangements (including grants, loans, and other forms of assistance) to support such scientific activities and to appraise the impact of research upon industrial development and the general welfare;

To award scholarships and graduate fellowships in the mathematical, physical, medical, biological, engineering, and other sciences;

To foster the interchange of scientific information among scientists in the United States and foreign countries;

To evaluate scientific research programmes undertaken by agencies of the Federal Government, and to correlate the foundation's scientific research programmes with those undertaken by individuals and by public and private research groups.

The National Science Foundation is the only agency of the Federal Government that exists solely for the support of uncommitted basic research (that is, research unrelated to the accomplishment of a specific mission) across all the fields of science and for the support of science education.

Other agencies are, of course, actively supporting research, both basic and applied, in the nation's colleges and universities. During the five-year period in which the National Science Foundation legislation was being debated, other agencies moved to fill the need for the support of basic research. The Office of Naval Research, for example, was established by Congress on 1 August 1946, with a broad programme in basic research that was related only very generally to the interests of the Navy. The United States Atomic Energy Commission was established by Congress in 1946 (amended by the Atomic Energy Act of 1954) and it supports a wide variety of basic research related to atomic energy. The medical research activities of the United States Public Health Service, which in 1930 were concentrated in the National Institute of Health, grew rapidly and a whole series of specialized institutes came into being; in 1948 the organization became known as the National Institutes of Health. Basic research is also supported by other agencies, such as the National Advisory Committee for Aeronautics (now expanded and reconstituted as the

National Aeronautics and Space Administration), the National Bureau of Standards, United States Weather Bureau, Department of Agriculture, and other agencies. Only two agencies, however, the National Science Foundation and the Smithsonian Institution, use their total research funds for the support of basic investigations.

During the greater part of its first decade, the foundation has divided its funds approximately evenly between the support of science and the support of science education. At the present time, however, with the needs of the colleges and universities for laboratories and equipment looming large (as will be discussed hereafter), the current trend is toward a greater effort in support of science. Thus, estimates for fiscal year 1962 show approximately 65 per cent of available funds for support of science, as against 34 per cent for science education.

SUPPORT PROGRAMMES OF THE FOUNDATION

Up to the present, support for basic research has been divided approximately equally between the mathematical, physical, and engineering sciences and the biological and medical sciences, but beginning with 1960, the balance began to be weighted somewhat on the side of the physical sciences.

Support for basic research in the social sciences, initially divided between the two natural science divisions, began at a very modest experimental level. In 1958, the programme was given the status of a separate programme, and support was increased. In December 1960, the director announced that the social sciences had been elevated to the full status of a division. Basic research in the social sciences is organized under four programme areas : (a) anthropological sciences—including ethnology, archaeology, linguistics, and physical anthropology; (b) economic sciences—including econometrics, economics and social geography, the economics of research and innovation and general mathematical economics; (c) sociological sciences—including demography, social psychology, psycholinguistics, mathematical social sciences and the sociology of sciences; (d) history and philosophy of science. Only those projects are supported that are susceptible to scientific approach and are truly fundamental in character.

Methods of research support

The general pattern under which Federal agencies support research at institutions outside the Federal Government, particularly universities, evolved out of the practices of the Office of Scientific Research and Development during the war in contracting with colleges and universities for the performance of research on specific problems. It provided the means whereby the Federal Government could benefit from important research carried on outside its

own laboratories. Today the method has been adapted to the support of research, somewhat as follows. The government encourages or invites research proposals from individuals or groups of scientists, submitted through their institutions. Then, with the help of individual reviewers in the field involved and of advisory panels appointed for this purpose, the federal agency selects for support those that are judged to have the greatest scientific merit. The foundation also has statutory divisional committees for over-all review of programmes in the four major areas—life sciences, physical sciences, social sciences, and scientific personnel and education.

This so-called 'project method' of research support has a number of advantages. Properly interpreted, the plan is flexible and may be applied either to narrowly defined problems in science or to broad areas. It enables the government to provide the support needed for promising and significant undertakings of current interest to the scientific community that might not otherwise be supported. It provides for a national programme in the sciences, utilizes the advice of the scientists in each field, and is based upon the significance and merit of the research proposed and the competence of the investigators. Since each grant and contract requires the official endorsement of the investigator's institution, the plan has evolved with the concurrence of the nation's universities and has had a most important indirect effect in helping to strengthen such institutions. In fact, such aid has often been of critical importance, particularly for the smaller schools.

The chief drawback of this method of research support is the difficulties it may create in departmental administration. The method has also been criticized on the grounds that the reviewing process is slow and that the resulting programme is too conservative.

In reply to these criticisms, it can only be said that the slowness of the process is the price one pays for operating on the basis of consultation and advice, rather than 'master-minding' the system from Washington. This disadvantage is probably offset by the great advantage of having the nation's scientific research and development problems widely understood by scientists as they participate in the solution of these problems. If the final results are conservative, it is because groups in general tend to become conservative, but each agency, including the foundation, is responsible for guarding against the conservatism that is apt to result from too much committee advice.

Breadth in project support

With the increased sums available to it for support purposes, the foundation is now able to make more grants of the broader type, often cutting across two or more departments of a university.

Some of the recent grants in this category may be of interest.

For example, the foundation has recently awarded a five-year grant to the

Rockefeller Institute to support the work of Fritz Lipmann on biosynthetic mechanisms. Dr. Lipmann, who with Hans Krebs was awarded the 1953 Nobel Prize in medicine and physiology for investigations which led to the discovery of coenzyme A, is pursuing his varied research interest in energy and amino acid metabolism. He is at present emphasizing the synthesis of proteins as a problem of paramount biological significance—for example, problems in metabolism: mucopolysaccharide synthesis, mainly concentrated on the sequence patterns in sulphated compounds; glycogen synthesis, aimed at understanding hormonal control; and conversion of phosphoryl potential into osmotic work. He hopefully intends to go further in the direction of protein phosphorylation.

A number of the distinguished members of the younger generation of microbiologists and biochemists are former students of Dr. Lipmann. The broad terms of the foundation's grant bring together all his activities within one agency and enable him to devote his creative energy to the things he does best—the pursuit of research and the education of the new generation of scientists.

In quite a different field is the three-year grant to the Massachusetts Institute of Technology for research in the communication sciences, under the direction of Walter A. Rosenblith. Communication science represents an important new research area, emerging from the researches of electrical engineers co-operating with scientists in other disciplines, such as experimental psychology, neurophysiology, and linguistics. The communication scientist is concerned with the generating, processing and transmission of information in its various forms. The theoretical foundations of the communication sciences rest largely on the basic work of Norbert Wiener on random processes, their prediction and filtering, and the mathematical theory of communication developed by Claude Shannon.

Knowledge in this field is applicable to problems of coding, of efficient transmission of information, of cryptography, of design of computers and automata, in the analysis of speech and language, in the transmission of signals through the nervous system, and in the study of the behaviour of groups and of learning itself. The Center for Communication Sciences, established at the Research Laboratory of Electronics, includes such research interests as statistical communication theory, processing and transmission of information, communication biophysics, neurophysiology, linguistics, speech communication, experimental psychology, automata and artificial intelligence, sensory aids, physical acoustics, circuit theory and network synthesis, and modulation theory.

In the social sciences, which lend themselves particularly well to the broad approach, the foundation is supporting a number of interesting grants of this type, including one to the Illinois Archaeological Survey for the investigation of the American Bottoms of the Mississippi River Valley, from Wood River

to Dupo, Illinois. This area is probably the largest aboriginal population centre in North America north of Mexico. It appears to have been one of the main centres from which Middle Mississippi culture spead, through colonization, to many areas throughout eastern United States and was apparently well established by about A.D. 900. Perhaps because of the enormous proportions of the task, very little archaeological work was undertaken in the American Bottoms before 1960, in spite of its central significance for mid-western prehistory. Since that time, large scale excavations concerned with Middle Mississippian sites have been carried out by the University of Illinois, Southern Illinois University, and the Illinois State Museum, financed by the Federal Aid Interstate Highway Archaeological Salvage Program.

The foundation's grant will finance a one-year co-operative programme of research by these three institutions that will focus on studying collections obtained under the Highway Salvage excavations and on the excavation and comparative study of materials and data relating to sites lying outside the highway rights-of-way. Broad problems such as the relationship between the subsistence base and the ecological adjustment of the communities in the American Bottoms, the relationship between these communities and those peoples living in the hinterlands, the evidence for social stratification, the role of ceremonialism, and the similarities and differences between these communities and the comparable prehistoric manifestations in other areas of the New World and the Old World can only be investigated through extensive research involving additional excavations and through detailed analysis of all available data. Although the principal objective of the research is the reconstruction of Middle Mississippi culture in the American Bottoms, it is also planned to make contributions to theoretical problems of broad interest to anthropologists concerned with processes of cultural development and growth.

Institutional grants for research

Federal support given to educational institutions for a particular research project judged primarily on its scientific merits tends to reduce somewhat the flexibility of university science departments in the planning and administration of their own research. As an experimental approach toward a solution of this problem, the foundation has initiated institutional grants to aid institutions in fulfilling their responsibilities for developing and maintaining sound, well-balanced programmes of scientific research and research-training activities without precisely specifying what activities are to be undertaken with the funds. The amount of such grants allowable to a particular institution for a given year is 5 per cent of the payments to that institution in basic research grants from the foundation during the preceding year. Such institutional grants are made on request and without requiring a prior statement regarding the use of the funds by the institution. A report on how the funds were used,

however, is requested. The plan is designed to permit each institution to exercise a greater degree of initiative with respect to its needs in scientific activities.

Graduate laboratory programme

Under the Graduate Laboratory Development Program the foundation provides funds on a matching basis for the modernization and equipment of research laboratories. Studies indicate that the graduate-level research laboratories of the nation's universities are obsolescent to a degree that is detrimental to the national basic research effort. The financial situation in which most of our institutions of higher learning find themselves makes it impossible for them to provide modern, well-equipped laboratories entirely out of their own funds.

This programme was initiated in a modest way in fiscal year 1960, and the budget for fiscal year 1962 provides for a substantial increase in the support level for this area.

Support of research facilities

Traditionally, universities and other private research organizations have provided needed research tools from their own funds of from funds available from state or local sources. Today, however, the need for such major equipment as nuclear reactors, high-energy particle accelerators, high-speed computers, and radio and optical telescopes is too great to be met from such local resources or even from the combined resources of several institutions. After studying the situation, a special advisory panel of the foundation recommended that, if American science was to advance at a satisfactory rate, federal support for the necessary facilities would have to be provided. This recommendation was endorsed and became national policy.

In embarking upon a programme in support of facilities, the foundation recognized that each case would have to be judged on its individual merits. It was impossible to establish criteria that would be applicable in all cases. Factors taken into consideration include the urgency of the need, the national significance of the development, the availability of adequate personnel, and the degree and character of local backing. Recipient institutions are encouraged to participate financially to the extent possible. The foundation has also recognized that in some situations the Federal Government must continue to supply funds for operation and maintenance, in addition to funds for construction.

The foundation is at present supporting two major facilities in astronomy: the National Radio Astronomy Observatory at Green Bank, West Virginia, and the Kitt Peak National Observatory at Tucson, Arizona. Both of these

projects were undertaken only after intensive studies by astronomers extending over a period of several years. Determination of the types of facilities and instruments needed was followed in each case by exhaustive search for suitable sites.

Similarly, in the autumn of 1960, the foundation announced the designation of Table Mountain, near Boulder, Colorado, as the site of the new National Center for Atmospheric Research. The purpose of the centre is to assist universities and other research institutions to increase, through co-operative basic research, knowledge and understanding of the atmosphere and the physical processes that govern its behaviour.

Other facilities being supported by the foundation include biological field stations, construction of an oceanographic research vessel, university computing facilities, and university nuclear research equipment.

PROGRAMMES FOR EDUCATION IN THE SCIENCES

The primary objective of programme activities in science education is to ensure an adequate supply of competent scientists and engineers by maintaining a high level of excellence in science education in the face of expanding enrolments, rapid changes in science itself, and the growing need for the products of scientific research and development. The demands upon the educational system have been growing faster than they can be met through the traditional processes. Extraordinary methods, therefore, have had to be developed to assist the educational system in the solution of its problems.

In developing its various programmes in education in the sciences, the foundation has been guided by certain broad principles. It has sought the aid of the ablest people concerned with improving education in the sciences in defining problems to be solved and in seeking solutions to these problems. All decisions with respect both to broad programmes and to specific grants are made on the basis of continuous consultation with members of the scientific and educational communities. The foundation is concerned with the substance of science, mathematics, and engineering, and its programmes are designed to encourage the leading scholars in these fields to take an active part in seeking solutions to problems which bear on the improvement of subject-matter instruction.

These programmes have been directed toward the solution of problems in four broad categories : (a) support of students of science, mathematics, and engineering; (b) aid to teachers of science, mathematics, and engineering; (c) the content of science courses; and (d) public understanding of science.

Within these categories, the principal programmes are: fellowships, institutes, special projects in science education, public understanding of science, course content improvement, and scientific manpower. They area dministered by the Division of Scientific Personnel and Education.

The fellowship programme

The fellowship programme is the oldest support programme of the foundation, inaugurated in 1952 with the pre-doctoral and regular post-doctoral programmes. As new needs have become apparent, additional programmes have been added: the senior post-doctoral programme in 1956; the science faculty programme in 1957; the co-operative-graduate, teaching-assistants, and secón-dary-school teachers programmes in 1959. After awards have been made for 1961, an approximate total of 17,000 graduate students and advanced scholars in science, mathematics, and engineering will have received fellowship awards, from among about 64,000 applicants.

The foundation also selects for honorable mention each year a number of highly qualified applicants who failed to receive fellowship awards. Many of those so listed are likely to receive fellowships from institutions which scan the honourable mention lists with great interest.

The institutes programmes

The foundation supports four principal types of programme: summer, academic-year, in-service, and advanced subject matter institutes, conferences and symposia. The summer institutes last from 4 to 12 weeks and make use of the time when teachers are normally free from classroom duties. These programmes are designed to aid teachers with limited science and mathematical experience or teachers who need to be brought up to date on current developments in their field. Academic-year institutes operate throughout the school year, in some instances making use of the summer also. Teachers taking part in these institutes must take leave from their teaching duties in order to do so. In-service institutes are held throughout the school year in after-hours periods and at week-ends. The advanced subject matter institutes, conferences and symposia vary in length and usually deal with advanced subjects and new techniques in relatively specialized fields. A typical advanced subject matter institute is conducted for about seven weeks during the summer and deals with critical areas of science and technology, such as oceanography and space navigation. The advanced subject matter conferences and symposia are also held in the summer, lasting from a few days up to four weeks.

The institutes are variously designed for college teachers, technical institution personnel, secondary school teachers and elementary school personnel. More than 30,000 teachers participate in these programmes annually.

It is still much too early to be able to make a valid assessment of these programmes, but it is cause for some satisfaction that in this way a significant proportion of teachers of science and mathematics have had some opportunity to become informed about current trends in their fields and new laboratory methods.

Special projects in science education

Programmes in this category include: (a) programmes directed toward secondary school students; (b) advanced science education programmes; (c) undergraduate science education programmes; and (d) public understanding of science. In the first category the programmes are designed to supplement the secondary school students' classroom training in science through lectures by visiting scientists; through financial support to state academies of science to enable them to develop local programmes for the improvement of science in the secondary schools; and through summer training for students of special ability and aptitude. The programme also makes available the travelling science libraries. It supports co-operative college-school programmes and school science clubs.

Programmes under advanced science education are directed toward predoctoral and post-doctoral scientists and toward the improvement of the scientific background of science teachers. The devices utilized include research experience, contact with leaders in scientific thought through advanced subject matter institutes, conferences and campus visits, and opportunities for study and discussion of problems in science education.

The undergraduate science education programmes are designed to provide greater educational opportunities for promising undergraduates in mathematics, science, and engineering. The undergraduate research participation programme brings undergraduate science majors into direct contact with scientific research, either during the academic year on a part-time basis or during the summer vacation on a full-time basis. The undergraduate independent study programme assists college students of high ability in the independent study, beyond the scope of their regular courses, of such subjects as theoretical mathematics, theoretical physics, theoretical chemistry, and astronomy.

Public understanding of science

Progress in science depends to a considerable extent on public understanding and support of a sustained programme of science education and research. At the present time, science is often mistakenly identified in the public mind with the results of applied research and technology: spectacular developments such as space vehicles and weapons systems; the applications of research to the cure of disease; and the bewildering array of modern machines and gadgets that are advertised on every side. There is inadequate understanding of the role of basic research and its fundamental relationship to progress in engineering and technology.

The foundation has broadly construed 'education in the sciences' to include, also, education of the public. The increasing significance of science and

technology in relation to public policy, both national and international, has made it urgent that the level of scientific literacy on the part of the general public should be markedly raised.

This is a relatively new area, and there is little experience to guide us in the choice of methods and techniques that will serve the purpose. To date, the foundation has supported a limited number of conferences and institutes in which scientists, science writers, editors and publishers have been brought together for the purpose of discussing the problems of communicating science to the layman. It is planned to expand these efforts and to enlist the support and advice of influential editors of the general-information media as well as the aid of the scientific community in devising other ways of communicating science to the public.

Course content improvement

Comparable in importance to the need for aid to students and to teachers of science is the need for improvements in curricula and course content. Science must not be poorly taught at any level or in any field. Attention must therefore be given to the content of science and mathematics courses, from the elementary through graduate courses in highly specialized fields.

The foundation has approached this problem in a number of ways. In some situations, support has been given to relatively small projects in limited areas where useful results can be anticipated. At the other end of the scale, a high level of support has been given outstanding investigators to enable them to attack a major problem in force. The work done by the Physical Sciences Study Committee at Massachusetts Institute of Technology, for example, has produced an entirely new approach to the teaching of physics, with a new syllabus, new textbooks, and a wide variety of new teaching aids and new methods and techniques of demonstration.

The success of the course revision work in physics prompted a similar large-scale effort in mathematics, guided by the School Mathematics Study Group, operating with headquarters at Yale University. The chemistry curriculum is being worked on by two groups, the Chemical Bond Approach Committee at Earlham College and the Chemical Educational Materials Study at Harvey Mudd College. The Biological Sciences Curriculum Study, with headquarters at the University of Colorado, is well into a thoroughgoing revision of the biology curriculum. Plans are being made for revisions in other fields also.

All course-content improvement projects involve trial use of the materials in the classroom and the resulting information is fed back into the study group for use in making such further revisions as seem necessary. Teachers are specially trained in the use of the new materials through intensive briefing sessions, through summer and in-service institutes, and sometimes by a

combination of both methods. Teachers who are thus trained then proceed to use the materials on a trial basis in selected experimental schools. In some cases special evaluation procedures are developed with the assistance of psychologists and testing experts.

The comprehensive review and revision of the four major science courses —physics, mathematics, chemistry, and biology—is unquestionably one of the most significant developments in the teaching of science in this country. Courses that are out of date by as much as 30 to 40 years are being brought abreast of modern developments. In the process of working together on this task, university scientists and secondary school teachers and administrators have come to see each other's problems and points of view as they could have in no other way.

The principal effort thus far has been in course content at the secondary school level, but consideration is now being given to the possibility of extending similar efforts downward into the elementary schools and upward into college-level courses.

DEVELOPMENT OF NATIONAL SCIENCE POLICY

In carrying out its obligations regarding the development of national science policy, the foundation started from the premise that national policy for science is a matter primarily to be determined by the scientists themselves. The scientists of the country are unquestionably the ones most capable of deciding what is best for progress in science; policy in this sense should not be 'master-minded' by the Federal Government or any single agency.

The foundation has advocated, and has itself adopted, the fairly general policy of providing support for basic research after consultation with leading scientists in their respective fields. This would appear to be the most direct way in which progress in science in the country can be determined by the scientists themselves. It is the method that is favoured by the majority of working research scientists.

In further development of science policy, the foundation's approach has been to examine particular issues and to develop recommendations through a variety of techniques and devices, as follows:

1. The establishment of a special committee or commission, followed by the issuance of a report. An example of this approach is the foundation's study of the problems of government-university relationships. This study availed itself of the assistance of outside individuals and groups, the foundation staff, members of the National Science Board, and representatives of other government agencies. Another example is the work of the foundation's Special Commission on Rubber Research, which made recommendations on the role of the government with respect to basic research in this field that were approved by both the President and Congress.

2. Preparation of special reports on particular subjects; for example, the foundation report on *Basic Research—A National Resource* (1957).
3. The use of experimental programmes by the foundation as a means of acquiring information and experience to provide a basis for policy recommendations. The various experimental programmes in science education, such as the Physical Sciences Study Committee, are examples of this approach.
4. Conduct of special studies and issuance of reports upon request of the Executive Office of the President.
5. Sponsorship of legislation on particular problems. An outstanding example is the successful foundation sponsorship of legislation to extend to all agencies of the government the authority to make grants for the support of basic research and the authority to vest the title of research equipment with educational institutions.

Studies in support of policy

As background data for its own research programmes and for policy formulation concerning the role of the Federal Government in the support of science, the foundation has established a continuing series of studies of the nature and extent of the national effort in research and development. Comprehensive surveys are made of the research and development effort of colleges and universities and other non-profit institutions and of industry. Initiated for the year 1953-54, these surveys measure research and development in terms of dollars expended, professional personnel employed, and apportionment of effort between basic research, applied research, and development. With 1953-54 as the base year, future surveys will afford data to indicate trends and analytical purposes. These surveys are in addition to the foundation's analyses of the support of research and development by federal agencies, published annually in *Federal Funds for Science*. The whole series carries out the executive order 'to make comprehensive studies and recommendations regarding the Nation's research effort and its resources for scientific activities. . . .

EVALUATION OF RESEARCH PROGRAMMES

A problem that matches in complexity the policy function is that of evaluation. The National Science Foundation Act makes the foundation responsible for the evaluation of scientific research programmes undertaken by agencies of the Federal Government and for a correlation of the foundation's scientific research programmes with those undertaken by individuals and by public and private research groups. The foundation has consistently pointed out, however, that it is unrealistic to expect one federal agency to render judgement on the over-all performance of another agency or department.

The foundation has chosen, instead, to approach the problem through

close liaison and exchange of information with other science agencies. The idea is to gain a comprehensive idea of the federal programmes and over-all support of *fields* of science such as physics, mathematics, and biology. The adequacy of federal support in each field may thus be considered. This procedure is implemented by the general technique of basing research support upon selection among applications or proposals received. By these measures the foundation has endeavoured to identify areas that are receiving inadequate support or which require attention for other reasons.

It was discovered, for example, that systematic biology and, more recently, inorganic chemistry were being inadequately supported. Word that the foundation would be receptive to proposals in the field of systematic biology has resulted in the rescue of this field from comparative neglect, and in all likelihood the same results will obtain with respect to inorganic chemistry.

Another example will serve to illustrate this point. A few years ago both the Office of Naval Research and the Atomic Energy Commission were providing considerable support to research on low-temperature physics. When the time came that neither agency felt justified in continuing its support at the existing level, the foundation agreed to take over the major support of research in low-temperature physics.

CRITICAL AREAS OF SCIENCE

A related matter that will call for increasing attention on the part of the Federal Government and other sources of support for research and development is the question of special emphasis on particular areas of science. The issue frequently arises in determining critical areas or, from another point of view, in identifying 'gaps'. In all developmental work, and in the search for areas of application, the importance of priorities of time and effort is an accepted fact. In pure science, the word 'priorities' is inappropriate and misleading. No field of science can properly be said to have priority over other fields, *as science*. However, at a given time, in a particular field of science, it is common to find special lines of inquiry that for the moment are making rapid progress or other lines of inquiry that are meeting difficulty. These considerations can be, and indeed are, taken into account both by individual research scientists and by research agencies concerned in research support. Thus, at any time there may develop what might be termed 'critical areas' that it is currently important to foster. If the urgency is great, a conference on the subject may be in order, or possibly a thorough study may be undertaken to ascertain what special facilities, equipment, or training are needed to encourage progress in the field. These are well-known techniques, in common use. It seems evident that, in years to come, increasing attention will be required along these lines, since there will undoubtedly be a tendency for groups of scientists to present for support plans and programmes that represent their

collective thinking. Agencies that provide support will then have to evaluate the needs of different groups in the light of current available information and knowledge—and funds. However, the existence of special patterns for critical areas should not be allowed to alter the view that support of research, across all fields of science, should be carried on on a continuing basis. Moreover, critical areas in such fields as defence and health that are closely related to the missions of specific agencies should be handled by those agencies.

INTERNATIONAL PROGRAMMES IN SCIENCE

International Geophysical Year. The International Geophysical Year marked the first time that the foundation had participated in international scientific activities on a large scale, and it also represented the foundation's first opportunity to co-ordinate a major activity being undertaken by a number of government agencies. The scientific and technical programme for the United States was developed and directed by the United States National Committee for the IGY, under the National Academy of Sciences. At the request of the academy, the foundation initiated consideration of IGY support by the Federal Government and, upon affirmative decision, secured and administered federal funds totalling $43.5 million. The foundation also served as co-ordinator of government interests in the programme; these involved not only direct participation by government agencies but also, quite often, matters of broad national policy that arise in an international programme.

Antarctic research. A major outgrowth of the International Geophysical Year has been the continuing research programmes in the Antarctic being carried on by some of the 12 nations who participated in the IGY Antarctic programme. The Antarctic Continent has since been reserved for peaceful purposes by the treaty now in the process of being ratified by the participating nations. General scientific recommendations are made by the Special Committee on Antarctic Research (SCAR) of the International Council of Scientific Unions (ICSU). The scientific portion of the United States programme is being developed, funded, and co-ordinated by the National Science Foundation. The latter looks primarily to the Committee on Polar Research of the National Academy of Sciences for broad programme recommendations, and considers as well proposals from qualified scientists interested in carrying out such research. The foundation co-ordinates the research activities of other agencies, such as the National Bureau of Standards, the Weather Bureau, and the Geological Survey, and provides them with funds for their participation in Antarctic research. Grants are also made to universities and other research organizations interested in performing scientific research in the Antarctic.

International science education. Beginning in 1959, the foundation undertook a modest programme designed to foster international co-operation and improve communications among nations with respect to problems of science education and scientific manpower. Appropriate professional groups in the various disciplines were given support for a study and evaluation of science subject matter offered in foreign educational systems, with the objective of improving science curricula in this country. Distinguished foreign scholars were brought here to visit the various institutes sponsored by the foundation. Advanced students and scientists have received foundation support to permit them to participate in international educational programmes.

A noteworthy development in the foundation's international programme was the establishment, in October 1960, of an overseas group in Tokyo. Japan was chosen as the location of the first such office because of the importance of its basic research and because of the increasing need for better communications between scientists of the two countries.

The representatives of the foundation study and report on Japanese science organization and funding, both private and governmental, and make similar information on American science available to Japanese scientific institutions.

One of the principal functions of the new group is to develop and promote the exchange of scientific information of a documentary nature. In this connexion, it assists in the publication in English of scientific articles and abstracts written by Japanese scientists and supports activities for translating and abstracting existing Japanese science information into English.

It also encourages the exchange of scientists between Japan and the United States and arranges surveys, reviews of research, and science education activities.

SCIENCE INFORMATION

The law that established the foundation authorized it to foster the exchange of scientific information among United States and foreign scientists and to provide certain types of support to further the dissemination of such knowledge. This provision was augmented in 1958 by action on the part of both the President and the Congress, directing the foundation to assume leadership in the co-ordination of the national effort to improve existing scientific information services, and to support the development of improved methods, including mechanized systems, for disseminating scientific knowledge. Such directives, and the foundation's implementation of them through its Office of Science Information Service (OSIS), reflect a growing recognition of the fact that dissemination of the results of research is an integral part of the research process, and that effective interchange of scientific information is essential to maximum scientific progress.

Programme activities in this area fall generally into four categories:

(a) documentation research; (b) support of scientific publications; (c) foreign science information; and (d) research data and information services. The first of these includes most of the work looking toward the development of new and improved techniques for handling and disseminating scientific information; the last three are concerned primarily with making more effective use of existing methodology.

Documentation research is sponsored along three principal lines. Because an understanding of the needs of users is a prerequisite to the intelligent planning of any service, one of these concerns the information requirements of scientists and engineers. A second comprises basic research on systematizing and mechanizing methods for storing and retrieving information—a problem whose solution requires the combined skills of computer experts, information specialists, librarians, linguists, logicians, and mathematicians. Closely related to this second area is the third—mechanical translation. Here basic research projects are supported that promise (a) to provide a better understanding of language and of translation problems and (b) to contribute to the development of automatic systems for mechanically translating foreign languages into English. Two publications are issued that concern research in scientific documentation; they are the semi-annual *Current Research and Development in Scientific Documentation*, and *Non-Conventional Technical Information Systems in Current Use*, issued at irregular intervals.

In supporting existing scientific publications, the foundation makes grants to primary and secondary journals to assist with the establishment of new publications, to help existing journals weather financial emergencies, or to enable them to perform certain important publishing tasks not possible within their regular budgets. Examples of currently successful journals which began as foundation-supported experimental publications include *Physics Review Letters* and *Chemical Titles*, published respectively by the American Institute of Physics and the American Chemical Society. In the case of monographs of various kinds, publication support is granted only when a significant manuscript cannot be published without subsidy. Any publication receiving support must, in the opinion of the foundation and a group of reviewers, both show promise of making a significant contribution to the scientific literature and be planned on an economically sound basis. The foundation also supports studies and experiments directly related to scientific publishing and conferences and other co-operative projects designed to facilitate joint attack by several organizations upon common problems. The Conference of Biological Editors, a permanent organization of editors and business managers of biological journals, was formed at one such meeting.

In its foreign science information programme, the foundation supports the translation of a variety of foreign scientific journals, monographs, and other documents, in the languages least familiar to American scientists. This is accomplished through grants to scientific societies, which are responsible

both for selecting the journals to be translated and for the quality of the product. This programme also has provided for the establishment and maintenance of two major translation depositories—one in the United States and one in Europe. Other foundation activities directed toward improving the flow to United States scientists of the results of foreign research include provision of state-of-the-art reviews of foreign scientific activity; support of studies and conferences in various phases of foreign scientific information; and close association with, and partial support of, the International Federation of Documentation and the ICSU Abstracting Board.

The research data and information services programme deals with non-conventional publication media and with specialized services and centres that provide information in ways other than through publication. For the former, the principal activity to date has been directed toward improving the availability of technical reports—the great bulk of which are issued by government agencies and contractors. Here foundation support has enabled the Office of Technical Services (Department of Commerce) to improve and expand its report announcement and availability service and the Library of Congress to establish a report reference centre. The foundation also has taken the lead in promoting co-operative efforts that are streamlining and speeding up several phases of report processing. Other non-conventional media include industrial reports and academic theses; some attention is being given to these and more is planned.

A fundamental foundation concern with regard to data centres and specialized information services has been to obtain an accurate picture of their number, size, and operating characteristics; to this end, preparation of a comprehensive directory of such activities is being supported. Examples of major information services receiving direct foundation support are the Office of Critical Tables (National Academy of Sciences), which is a co-ordinating and information centre on projects engaged in developing critical physical data, and the Science Information Exchange (Smithsonian Institution) which is a depository of information on research in progress in the biological and physical sciences; the latter evolved from and incorporates the former Bio-Sciences Information Exchange.

Substantially all of the activities mentioned above involve to some degree the foundation's national co-ordinating responsibility in the scientific information field, since all require consultation with others who are concerned and permit the foundation to exert its influence toward the development of a unified, effective total system. Its co-ordinating role is played somewhat more explicitly in the numerous groups it calls together to discuss mutual scientific information problems and develop solutions beneficial to all. To provide an effective medium for the broad dissemination of information and news in the scientific information field, the foundation publishes a bi-monthly journal, *Scientific Information Notes*.

CONCLUSION

After ten years of operation, the programmes of the National Science Foundation are now so integral a part of the academic community that the only surprising feature is perhaps that the Federal Government should have waited until so late a date in its history to institute this type of support for basic research and education in the sciences. The foundation's programmes, together with those of other agencies who are supporting basic research related to their missions, represent an estimated annual expenditure of $833 million for basic research in 1961, primarily in the nation's colleges and universities.

Foreign critics have sometimes asserted that the United States draws artificial distinctions between basic and applied research, and distinguishes unnecessarily between the educational and research aspects of the training of scientists. Such criticisms may well be valid, but it should be borne in mind that until the last decade or so, basic research, in contrast to applied research and development, had been seriously neglected in the United States. Since, in the words of Vannevar Bush, 'applied research tends to drive out basic', there must be a focal point of emphasis for the more intangible types of investigation that are classed as basic research. Another point is that, in contrast to the situation in most other countries, higher education in the United States is not supported by the Federal Government but derives its support from private funds in the case of the private institutions, and from state governments in the case of public institutions. Therefore, when it became apparent that basic research in the United States required support beyond the capacity of traditional sources, it became necessary to supplement existing funds with federal money. Strong support for applied research and development is afforded by American industry; and since World War II, federal funds also have been available for support of research of this kind in the form of contracts for the solution of specific problems.

So far as the education of scientists is concerned, it is recognized at the highest levels of government that both teaching and research are indispensable elements in this process and that one cannot be considered independently of the other. This point of view was recently reiterated by the President's Science Advisory Committee in a significant report entitled *Scientific Progress, the Universities, and the Federal Government*. In a country as large as the United States, many institutions of higher learning of various types are involved and it has been necessary to consider and devise ways of meeting many elements of the problem. That is why in the case of the National Science Foundation there are a number of programmes with different immediate objectives, all directed ultimately toward the improvement of education in the sciences.

To summarize, it may be said that in the course of its ten years of operations, the foundation has evolved three approaches directed to the strengthening of science and science education in the United States. The first is the support

of individuals through such measures as: research grants made to their institutions on their behalf; graduate fellowships in a variety of categories; teacher institutes directed toward the enrichment of the substantive background of individual teachers; the undergraduate research participation programme designed to stimulate the interest of young students in the potentials of a research career; travel grants to enable qualified scientists to travel to important meetings abroad. The second is direct support to the institution in the form of institutional grants and the development of graduate research laboratories. The third might be termed support for physical plant, in the form of grants for new facilities, observatories, computer centres, biological field stations, research vessels, and so on.

For the future it is anticipated that the funds made available to the foundation by the Congress will continue to grow at a rate commensurate with the need. To date, the number of proposals that the foundation has received for assistance in all categories has been considerably in excess of the funds available to meet them. One hesitates to predict the course that the foundation is likely to follow in the years ahead because scientific and technological change occurs so rapidly and is so unpredictable that new and unforeseen developments may create needs in all sorts of unexpected areas. In general, however, it may be anticipated that the needs for individual support will level off before the needs of institutions for both uncommitted funds and funds for physical plant can be met. This is partly because the rapid advance of technology has produced requirements for all sorts of new and costly research instruments and partly because there is in the universities a large backlog of unfilled needs for both plant and equipment. The principle of local control of education is still jealously guarded in the United States and is not likely to be altered, but it seems quite clear that the complex and costly needs of science and technology have rendered imperative a mounting level of federal support—in many important respects, at least—for institutions of higher education.

As science and technology have become increasingly important to the strength and welfare of nations, each nation has had to work out its own pattern for the support and encouragement of both research and research education. For the newer nations which have not yet evolved such patterns, the experience of the United States with its National Science Foundation and other agencies for research support may be of particular interest. One thing at least is clear, and that is that in basic research particularly a nation can be no stronger than the collective strength of its institutions of higher learning and its research centres. These in turn depend directly upon the strength and effectiveness of elementary and secondary school education, so that in effect, a nation's scientific potential is closely linked to the strength of its entire educational system. In the United States we have been trying to remedy what we see as weaknesses and shortcomings in our educational system.

Nations that are just starting out have the benefit of being able to observe the mistakes and omissions of older nations as well as to profit from these if they wish.

Science and technology are a great common denominator among nations; they have great potential for universal good. Furthermore, each nation has the opportunity to contribute in a large or small way to the fund of common knowledge and at the same time to benefit from the whole.

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FRIDTJOF NANSEN

by

JAC. S. WORM-MÜLLER

Dr. Jac. S. Worm-Müller, Professor of History at the University of Oslo from 1919 to 1954 and historical adviser at the Nobel Institute since 1919, was a delegate to the League of Nations in 1926 and 1927 and has since represented his country at various meetings at the United Nations. He was an intimate friend of Fridtjof Nansen and edited Nansen's diary from 1905 (published in 1955). Dr. Worm-Müller has written numerous works on Norwegian history and has contributed to many periodicals and collective works, including the History of Norwegian Navigation.

Fridtjof Nansen was born on 10 October 1861[1] at Store Frøen, not far from Oslo (then Christiania), Norway. The son of a lawyer, he received a university education and in 1882 was appointed curator of zoology at the Bergen Museum, a post which he held until 1888, the year in which he was awarded his Ph.D. After relinquishing this appointment Nansen embarked upon an expedition to Greenland, the first of the hazardous journeys which were destined to win him international acclaim and give added lustre to his country's name.

Nansen was married twice : his first wife, Eva Helene (*née* Sars), died in 1907 and he remarried in 1919. He died at Lysaker, on the outskirts of Oslo, on 13 May 1930, an internationally famous figure whose passing was mourned throughout the entire civilized world.

THE SPIRIT OF ADVENTURE

In his rectorial address, 'Adventure', delivered at St. Andrews University on 3 November 1926, Nansen referred to his two distinguished predecessors in the rectorial chair, Barry and Kipling, who had dwelt upon the virtues of courage and independence, 'two heaven-born qualities for this voyage of life, and never more needed than in our day. . . . But', declared the great explorer, 'a third genius is needed to complete the group of deities—it is the *spirit of adventure*, the urge for achievement'. In his book *Nord i Täkeheimen* (In Northern Mists) Nansen quotes from a mediaeval Norwegian classic, *Kongespeilet* (The King Mirror), a passage which perfectly sums up his own sentiments. When people wonder what prompts those men who journey far into the unknown at the risk of their lives, the answer is in part 'the spirit of competition and the desire for fame, because it is in the very nature of man to journey

1. This centennial article is published in accordance with the decisions adopted by the Executive Board of Unesco at its fifty-fifth session concerning the commemoration of anniversaries of great personalities and events.

to places where he is exposed to great danger, and in so doing to win renown. Another contributory factor is the thirst for knowledge, because again it is natural for man to want to get to know and to see at first hand places of which he has heard, to ascertain for himself whether they are as they are reputed to be, or not'. These qualities—courage, independence, a spirit of adventure, and an urge to achieve something—were characteristic of Nansen himself and were afforded full expression in the great voyages of exploration he undertook as a young man and indeed throughout his whole life of service to humanity. They were qualities that had always been greatly in evidence on both sides of his family.

In 1614, one of his ancestors, Hans Nansen, then only 16 years of age, sailed to the White Sea from Flensburg in a ship belonging to his uncle. The vessel was trapped in the ice off Kola, but the experience did nothing to dampen the ardour of young Nansen. He seized the opportunity thus offered to learn Russian, and when with the coming of summer his uncle sailed for home, Nansen made his way back to Copenhagen alone, through Russia. When he was not more than 21 years old he was appointed by King Christian IV to lead an expedition to the territories near Petsjora, in search of furs. Later he spent 18 summers voyaging in Arctic waters on behalf of the Iceland Company. This Nansen was a versatile character and published a *Compendium Cosmographicum* dealing with astronomy and physics, geography and chronology, navigation, etc., a work of considerable value which was much in demand at the time. His reputation was rapidly enhanced, and he was eventually made burgomaster of Copenhagen, in which capacity he supervised the city's defence when the Danish capital was besieged in 1658. Hans Nansen and his still more famous descendant Fridtjof had much in common.

From both his parents Fridtjof Nansen inherited the qualities that went to make up his character, among them fearlessness and independence of spirit, a strong will, truthfulness, and incorruptibility. These qualities were moulded and strengthened by the influence of the home in which he grew up. Nansen's father was a man who inspired confidence among his fellows: though capable on occasion of strictness, he never allowed his own will to hamper his son's development. The mother was capable and strong-minded, but equable and direct, free from pretentiousness arising from the circumstances of her birth and family connexions. She enjoyed skiing, a sport which at that time was regarded as being exclusively a male province, was altogether dauntless, and was practical to a degree. The estate at Store Frøen where Fridtjof Nansen was born and spent his childhood was a paradise for a healthy youngster such as he, situated as it was in rural surroundings which offered unrivalled facilities for skiing in the hills, hunting and shooting in the woods, and fishing in the lakes and streams. Nansen's parents brought their children up to be content with the simple things of life, to be frugal, and to a proper appreciation of human values. Throughout his entire life Fridtjof Nansen was personally

undemanding and was able to comport himself as naturally under the most primitive conditions as in the company of kings.

Nansen attended a school in Christiania, but though his abilities were well up to those of his classmates, there were times when his many outside interests prevented him from doing brilliantly at school. In the subjects that interested him he learnt all that was to be known, his trained powers of observation, lucid mind, and unfailing memory enabling him to grasp and retain a wide variety of knowledge. He was possessed by the urge to comprehend and accordingly was indefatigable in his inquiries into the whys and wherefores of all that came before him.

ZOOLOGICAL RESEARCH

Nansen matriculated in 1880 and took his moderation the following year. His interests and talents were so diversified that he was in doubt as to the subject he should take at the university, but finally resolved upon zoology, as he thought this would afford him excellent opportunities of leading an outdoor life and maintaining a close aossciation with nature in the course of his daily work. Subsequently he was to regret this decision and to wish that he had studied physics instead; it later seemed to him that the years he had spent as a zoologist had not been as well utilized as they might have been. He regretted not having acquired a better grounding in physics and mathematics, but it is highly probable that had he received an ordinary university education and become a physicist, he would never have embarked upon the voyages of exploration and polar research in which he first made his name. While Nansen was still at university, one of the faculty, Professor R. Collett, advised him to join a sealing expedition to the Arctic, a voyage that would enable him to combine his scientific interests, his love of the outdoors, and his abilities as a sportsman. As a consequence, in March 1882 Nansen sailed with the sealer *Viking* to the sealing grounds north of Jan Mayen.

This voyage was to prove of decisive influence to Nansen's subsequent enterprises. His heart and mind were captivated by the beauty of the Arctic wastes and by the vastness and ruggedness of their solitary expanses, where he discovered that his physical and mental powers were able to find release in action. Ever afterwards he was to remain under the spell of the polar regions.

Immediately upon his return to Christiania in the autumn of 1882 Nansen was offered a post as conservator of zoology at the Bergen Museum. He accepted, though he had no scientific training as a zoologist, apart from his university course, and threw himself into the activities of the museum, where he received valuable aid and encouragement from the director of the museum, Dr. D. C. Danielssen. Nansen's first important work, *Notes on the Anatomy and Histology of Myzostomida*, was published in 1885. This paper, which contributed in several respects to the knowledge of these parasites, won him the

Joachim Friele Gold Medal. Later in the same year Nansen published a second work, *An Interim Report on Research into the Histological Structure of the Central Nervous System in Ascidiacea and Myxine Glutinosa.* This was the forerunner of a more detailed work which appeared in the Bergen Museum Year Book for 1886, *The Structure and Combination of Histological Elements of the Central Nervous System.* In the meantime (1886) Nansen spent some months in Italy, where in Pavia he acquainted himself with Professor Golgi's recently evolved method of dyeing nerve fibres. He was the first person in Norway to grasp the value of this method to histological research, and in order to master it completely he proceeded from Professor Golgi's laboratory to the zoological station in Naples, where he was given access to an abundance of research material.

In the course of his investigations into the intricacies of the spinal cord, especially in *amphioxus* and *myxine* (hag-fish), Nansen made some highly important discoveries. It was for this work that he was awarded his Ph.D. at Christiania University in 1888. The value of this work was not fully recognized at the time, and it was subjected to considerable criticism. This was a case, so often to recur in Nansen's career, of his being in advance of his times : for today, the great importance of the work is acknowledged, and by many authorities it is regarded as a classic in the literature of zoology.

Undaunted, Nansen continued his studies of *myxine.* In a paper printed in 1888, *A Protandric Hermaphrodite Myxine glutinosa, L, amongst the Vertebrates,* he put forward the view that in the early stages *myxine* is male, but subsequently changes sex and becomes female. This discovery of the hermaphroditic qualities of *myxine* was made almost simultaneously by the English zoologist Cunningham. Together with Professor Gustav Guldberg, Nansen made important investigations into the life-cycle of the whale, a paper on their findings being published in 1894. This was Nansen's last published scientific zoological treatise, with the exception of one on protozoa found in the ice of the Polar Sea and another, compiled in collaboration with Professor Collett, on the birds of the polar regions; both these works were included in the full-scale report on the scientific results of the *Fram* expedition.

THE FIRST CROSSING OF GREENLAND

While Nansen was on board the sealer *Viking* in 1882 the ship entered the northern part of the strait between Iceland and Greenland, where it remained trapped in the ice for 24 days. The vessel was carried so close to what was then an unexplored part of East Greenland, that the land was clearly visible to those on board. 'Not unnaturally, this *terra incognita* caught and tugged at my youthful soul', wrote Nansen. 'Unceasingly I pondered plans for reaching this coast which so many had attempted in vain.' One day the following autumn (1883) the newspapers carried a despatch concerning Nordenskjöld's expedi-

tion to the inland ice of Greenland, and mentioning the two Lapps who had penetrated some distance inland across this ice on skis. 'It came to me like a flash of lightning', declared Nansen. 'An expedition across Greenland from coast to coast. The plan was ready, cut and dried in the form in which it was later to be submitted and put into operation.' The first written draft of the Greenland expedition is to be found in the jottings on which Nansen, then in a military training establishment, based a letter dated 17 June 1884 to Captain A. Mourier, a Danish naval officer stationed at Gardermoen, near Oslo. In this letter he explained that he was engaged on plans for an expedition to the interior of Greenland on skis and observed: 'I see no reason why, of the many tasks confronting scientific research in the polar regions, this should not prove to be a comparatively easy one.' The final plan for the expedition to Greenland was published in the January 1888 issue of *Naturen*.

At that time only the haziest idea existed of what conditions were like in the interior of Greenland. Nordenskjöld, in company with many others, thought that the inland areas were largely ice-free; and it was widely held that temperatures there were relatively high. Nansen had no faith in these beliefs, and said so in no uncertain terms. 'It is no use trying to work out or guess what the interior of Greenland is like. This is the age of empiricism: let us first see. Often enough one small observation has been sufficient to upset an entire system based on dogmas and theories.' On this expedition Nansen intended to study topographical conditions, carry out geological and meteorological research, and study the earth's magnetism. His plan was to cross the inland ice from east to west. This would almost rule out the temptation to turn back, while the thought of the inhabited west coast ahead would prove all the more enticing. 'I have always thought that the much-praised 'line of retreat' is a snare for people who wish to reach their goal', Nansen declared in his St. Andrews address.

Nansen's attempts to raise funds for the expedition met with no response in Norway, but eventually he received the 5,000 kroner for which he had applied from Augustin Gamél, a councillor of state in Copenhagen.

The whole undertaking was considered by many to be an act of folly, but in the event Nansen was largely enabled to do all he had set out to do when, in 1888, he made the journey with five companions (Otto Sverdrup, O. C. Dietrichson, Kristian Kristiansen, and the two Lapps—Samuel Balto and Ole Ravna).

The party left from Iceland, on the sealer *Jason*, bound for the Denmark Strait. The intention was to reach the Sermilik Fjord and from there to set out across the interior of Greenland. On 17 July 1888 the *Jason* was so close to the shore near the Sermilik Fjord that Nansen and his companions lowered two boats with the intention of forcing the narrow belt of drift-ice which separated them from the mainland. When they had penetrated some distance into the ice, however, it closed in upon them with such pressure that they found themselves unable to proceed. The current was exceptionally strong

at this point and the expedition was compelled to drift southwards with the ice for 10 days, in the face of great difficulties and danger, before the ice released its grip sufficiently to enable them to pull free and row ashore. By this time, however, they were many miles to the south of the spot where Nansen had originally planned to make a landing. The involuntary detour had put them considerably behind schedule, but though time was precious Nansen resolved to row northwards in the open channel close to the shore, to bring them nearer to their projected starting point. They slaved at the oars right up to 10 August, by which time thay had reached the Umivik Fjord; here they landed and commenced the ascent towards the interior. If the expedition was to entertain any hope of crossing safely to the west coast, they would have to make all possible speed, thus precluding any scientific investigations which would appreciably delay their progress. Despite this, many valuable observations were made and these did much to clear up the doubts that existed as to conditions in the heart of Greenland. The lowest temperature recorded was –45°C. On 14 September the party reached the highest point on their route, 2,716 metres above sea-level. Ten days later, on 24 September, they left the ice behind and the next day reached the Ameralik Fjord. Here Nansen and Sverdrup improvized a boat from sail-cloth, in which they rowed for six days, entering Godthaab on 3 October; on landing they at once despatched a body of men to bring in the rest of the party. By this time the last ship of the season had long since left West Greenland, so the members of the expedition had no choice but to spend the winter at Godthaab. Nansen seized the opportunity thus presented to study the habits of the Eskimos, living in their igloos, working alongside them, and accompanying them on their long journeys; in the process he learnt to paddle a kayak and to handle Eskimo tools and weapons.

The expedition left Greenland in April 1889, arriving in Christiania on 30 May. In the Norwegian capital Nansen and his companions were given an enthusiastic welcome and their feat aroused widespread admiration.

The expedition's findings were carefully studied by Nansen and Professor H. Mohn, and a treatise on the scientific results, *Ergänzugsheft* 105 *zu Petermanns Mittheilungen*, was published in 1892. The chief fact which emerged was that Greenland is covered by a domed ice-cap, with nunataks only on the fringe, and that the interior forms a vast cold pole. Other matters which had been the subject of dispute were elucidated, and a number of previously held theories proved to be unfounded. Nansen had presented the world with a clear picture of conditions in Greenland, just as, some years later, he was destined to do with regard to another great Arctic tract, the Polar Sea.

Nansen has given his own account of the expedition in his book *Paa ski over Grönland* (The First Crossing of Greenland), first published in 1890, which contains, among other things, a detailed description of the history and development of skiing. His book *Eskimoliv* (Eskimo Life), which came out

in 1892, contains the best account ever written of the lives of Greenland's Eskimo population towards the close of last century.

ADRIFT IN THE POLAR SEA

Upon his return to Norway in 1889 Nansen was appointed curator of the Zootomy Museum at the University of Christiania, but soon commenced work on plans for his next great research expedition to the Arctic. As early as the beginning of 1890 he outlined his plan for an expedition to the North Pole, in an address to the Norwegian Geographical Society, which had been founded after completion of the Greenland expedition. The text of his speech was published in the March number of *Naturen* that same year. Nansen's presentation of this plan was thorough in every detail and amply backed by documentary evidence for, in fact, he had had it constantly in mind for some five years or more. In November 1884 Professor Mohn had delivered a lecture to members of the Norwegian Academy of Science in Christiania on certain pieces of wreckage which had recently been found near Julianehaab. These derived from an American ship, the *Jeanette*, which had foundered off the New Siberian Islands and the professor asserted that in all probability they had been carried from the vicinity of the islands by a current which flowed right across the Polar Sea and merged with the East Greenland polar current. Nansen read a newspaper account of this lecture and came to the conclusion that it ought to be possible to cross the polar regions in a ship, drifting with the ice. The more he thought about it, the more firmly convinced did he become that there must be a current and that it would be possible to build a vessel of such shape and strength as to enable it to withstand the grinding and crushing of the ice. His plan was to sail this ship into the ice north of the New Siberian Islands and allow it to be carried along by the pack-ice. Nansen thought the expedition would 'be away for three years, or, rather, three winters and four summers, neither more nor less'. As soon as it became known, the plan was assailed by many self-styled experts as being foolhardy and suicidal, as had been the case with the Greenland expedition before it. Nansen stood firm against the body of expert opinion and once again he was to be vindicated, even his estimate of the time that would be required for the drift through unknown waters subsequently proving correct. His impartial thinking and assessment of the natural conditions triumphed. Nansen made his preparations for the expedition with meticulous care and applied himself to the technical side of the enterprise as to a scientific problem. Colin Archer brought to bear on the task of building a vessel capable of standing up to the onslaught of the pack-ice all his great experience and authority. Nansen devoted himself to a thorough study of such matters as clothing and the materials and designs to be used for skis and sledge-runners to suit the varying temperatures and snow conditions, and—a matter of special importance—in collaboration with Professor Torup he tackled the vital question

of what food supplies should be taken to prevent outbreaks of the scurvy and other ailments that had caused such suffering among the members of earlier Arctic expeditions. The benefits resulting from all these careful preparations were to prove unique in the history of polar exploration, and inaugurated a new era in the fitting out of Arctic expeditions; Nansen's pioneer work has been of inestimable value to all subsequent undertakings of a comparable nature.

The Government, King Oscar, and a number of private citizens put up the money required to finance the expedition, about half a million kroner being raised. The ship that was to make the hazardous voyage was built in Larvik by Colin Archer and named the *Fram*. Volunteers to take part in the enterprise were quickly forthcoming, the final choice falling on the following: Otto Sverdrup (captain of the *Fram*); Lt. Sigurd Scott-Hansen, R.N.N. (in charge of meteorological, astronomical, and magnetic observations); H. G. Blessing (medical officer); T. C. Jacobsen (mate); A. Amundsen (first engineer); A. Juell (quartermaster and cook); L. Pettersen (second engineer); Lt. F. Hjalmar Johansen (who served as fireman); and P. L. Hendriksen, B. Nordahl, and I. Mogstad. In Tromsø an extra hand, B. Bentsen, was hired, so that in the end the expedition comprised 13 men.

The *Fram* set out from Christiania on 24 June 1893. On the voyage northwards along the coast she put into Bergen, Beiarn, Tromsø, and Vardø, leaving the last-mentioned port on 21 July. The next port of call was Khabarova in the Jugor Strait, where the ship embarked 34 Samoyed dogs which Nansen had ordered to be transported there from Siberia.

On 3 August Nansen's secretary, O. Christofersen, left the ship with the last batch of letters. That same night the *Fram* set out, eastward bound, on the voyage that was to take her beyond the eyes of the civilized world for three long years. While crossing the Kara Sea the *Fram* occasionally found herself in 'dead water'. On 10 September Cape Tsjeljuskin was made and left astern. On this passage they hove to at times and went ashore to make observations and to supplement the larder with fresh meat which fell to their guns. On 20 September the expedition reached the margin of the ice north of the New Siberian Islands, and from 22 September on the *Fram* was firmly in the grip of the ice. On the whole the vessel drifted in a north-westerly direction, but the party experienced many reverses which gave rise to disappointment. The ship was exposed to considerable pressure from the movement of the ice, and at times was lifted on high; but never did this result in any damage. Nansen and his fellow explorers were convinced that the *Fram* would stand up to whatever batterings she might receive, but Nansen realized that they would not drift as far to the north as he had hoped. Accordingly, in the summer of 1894 he began to consider the feasibility of leaving the *Fram* in order to journey by sledge, with a chosen companion, as far north as possible, returning via Franz Josef Land. His object was to explore as much of the Polar Sea as

possible to the north, but he made no secret of the fact that he would dearly like to reach the Pole itself. In November, after having conferred with Sverdrup, he decided to undertake this journey by sledge, and set about serious preparations for the trip. It was impossible for him to take Sverdrup along with him, as he had to take over full responsibility for the ship and her crew. Everyone was eager to accompany Nansen on this perilous enterprise, but the final choice fell on Hjalmar Johansen.

Nansen and Johansen set forth on 14 March 1895 with 28 dogs, three sledges, two kayaks, and a tent. They carried with them sufficient food to last them for 100 days and enough to last the dogs for 30. The position of the *Fram* when they left her was 84°N. 102°E.

When conditions were favourable the pair made over 12 miles a day towards the north, but there were times when their progress was considerably hampered and they had to fight for every yard. Early in April the going became so bad that Nansen, with time becoming a pressing factor, determined to turn south once more. This was on 7 April, when they had reached a latitude of 86°4′N. (originally calculated by Nansen as 86°14′, but later corrected). After many days of hardship and peril they finally reached a point that was so far south that on 24 July—132 days after they had set out—they sighted land. Thirteen more days of inhuman toil were needed before they could step ashore—on what proved to be an unknown island to which Nansen gave the name Eva Island. They paddled onwards in their kayaks among the islands of Franz Josef Land until Nansen, realizing that they stood no chance of reaching human habitation that year, decided that they would have to spend the winter where they were. They made camp on 26 August on an island, where they built a primitive shelter of rocks, walrus hide, and ice-blocks; here they spent the winter months, relying for food on the polar bears they were able to shoot. On 19 May 1896 the two explorers struck camp, paddling and sailing their kayaks further to the south. Cape Flora hove into sight on 17 June, and there they encountered Frederick Jackson and his party. Jackson took them back to Norway on his ship, the *Windward*, which made Vardø on 13 August. From Vardø Nansen sent a telegram to Christiania to say that he expected the *Fram* home that same autumn. One week later the *Fram*, still in excellent shape, put into Skjervøy, after having drifted on across the Polar Sea and escaped from the clutches of the ice north of Spitsbergen.

This happy homecoming of Nansen and the *Fram* and the account that was given of their amazing adventures aroused the enthusiasm and admiration of the entire world, and won for the expedition and its leader international acclaim. After a triumphant voyage down the length of the Norwegian coast, Nansen and his stout vessel entered Christiania harbour on 9 September, there to receive a welcome the like of which the capital had never known before.

At the instigation of Professor W. C. Brøgger a nation-wide appeal was made for money to establish a fund to be known as the Fridtjof Nansen Fund

for the Promotion of Science. With the passage of time this fund has become a factor of very great importance to the cause of science in Norway.

After the successful completion of the *Fram* expedition Nansen found his time fully occupied. He wrote *Fram over Polhavet* (Farthest North), which was published in 1897 in two large volumes, and gave countless lectures on the expedition in a wide range of countries.

THE OCEANOGRAPHY OF THE ARCTIC

The *Fram* expedition had a great influence on the general public, especially the younger generation, and ensured for Nansen a fame and authority in many countries which paved the way for his subsequent activities, national and international alike. But the expedition was also of signal scientific value, and as such its importance can scarcely be overrated. The major geographical result was the discovery that the Polar Sea was several thousand metres deep. Prior to Nansen's voyage of exploration most geographers had thought the sea to be shallow, dotted with islands and possibly with large tracts of land, and many remarkable conjectures were made as to the conditions obtaining in these regions; thus the first-hand account brought back by Nansen caused quite a stir. Added to this, in many fields observations had been made, information recorded, and specimens collected which were to prove of fundamental importance not only in probing the secrets of the Arctic territories, but also in certain aspects of natural research in general. Nansen's investigations comprised meteorology, earth magnetism, the aurora borealis, geology, and zoology, as well as various aspects of oceanography, including conditions on the sea bed, marine physics, currents and other movements of the water, ice conditions, and marine flora and fauna. The scientific findings of the expedition were published in six large volumes, *The Norwegian North Polar Expedition, Scientific Results*, which came out in Christiania between 1900 and 1906. Nansen himself was most interested in the oceanographic studies. Even while the expedition was still in progress he made observations which prompted him to pose problems and draw up working hypotheses of great and general significance to students of oceanography. On his return to civilization he pursued these studies still further, and also initiated important theoretical investigations which were to be carried out by others on the basis of information supplied by him. In many ways oceanography entered into a period of strong development after this expedition. Of the results obtained by Nansen, space permits reference to only a few of the most important.

Nansen proved that the waters of the deep Polar Sea for the most part maintain a temperature below 0°C. with relatively slight variations. Below the surface, however, there is a layer of water some hundreds of metres deep, where the temperature is above 0°C. This is a remote effect of the Gulf Stream, which Nansen showed was still to be found as far east as north of the New

Siberian Islands. He had expected to find traces of the Gulf Stream in the Polar Sea, but not as far east as he did; it also came as a surprise to him to find how deep this ocean actually is. In the water below this warmer layer, the temperature falls to −0.7 or −0.8°C, only to rise again slightly as the sea-bed is approached. This rise, in Nansen's opinion, is attributable to the heat emanating from the interior of the earth, but he also knew that the temperature would rise with the increase in pressure resulting from sinking bodies of water—the adiabatic effect. This was a question to which Nansen's investigations gave topical interest, and which has since been the object of considerable study in other oceans. At great depths the temperature was found to be higher than in the Norwegian Sea; this led to the conclusion that there must be a ridge between Spitsbergen and Greenland. This assumption has been borne out by subsequent investigations, and the ridge concerned has been named the Nansen Ridge.

By comparing wind conditions with the drift of the ice (i.e., the *Fram*), Nansen established that generally speaking the drift was not in the direction of the wind, but to the right of it. He took this to be a consequence of the rotation of the earth, which in the northern hemisphere causes the moving water to circulate in a clockwise direction. He reasoned further that in view of this the water in which the ice drifted must likewise tend more and more to the right the deeper one got. On his return to Norway Nansen prevailed upon the Swedish physicist and mathematician V. W. Ekman to study the theoretical aspects of the problem, and Ekman's findings have since played an important role in oceanography and confirmed Nansen's theories.

Having in mind his experiences with the *Fram* in dead water, and realizing that the phenomenon occurred only when a comparatively thin layer of light water lay on top of heavier water, Nansen urged Dr. Ekman to subject this matter, too, to experimental and theoretical investigation. The puzzle of dead water proved to be a result of certain waves which formed on the boundary between the light surface water and the water beneath. On sifting the mass of *Fram* observations Nansen showed that there were in all probability also other wave effects (vertical oscillations) in deeper water, a theory which has been borne out by subsequent research.

During the first phase of the expedition, when the route took the party close to land, and later on the islands of Franz Josef Land, Nansen made numerous observations relating to geomorphological and glaciological conditions. As early as during the crossing of Greenland his interest had been aroused by various questions regarding the relationship between land and sea, and especially the rising or sinking of firm ground or of the surface of the sea. During the *Fram* expedition he was struck by the broad, flat bank, where the water was shallow, north of Siberia. In one of the articles that formed a part of the scientific account of the expedition, 'The Bathymetrical Features of the North Polar Sea', Nansen discussed coastal banks, or shelves, in general. He came to the conclusion that the banks to be found off the continents of the

world and round about islands were in the main formed at times when the surface of the sea was on a lower level in relation to the land than it is today, just as beaches and shorelines were determined when the sea was higher in relation to the land. Nansen subsequently pursued the matter further, detailed accounts of his findings appearing in Academy of Science publications in 1922 and 1927; the former dealt with the Norwegian coastal platform and isostasy, the latter with the earth's crust, its surface forms, and isostatic equilibrium. These works contain a great deal of factual information and much interesting and weighty discussion on the up and down movements of the earth's crust or the surface of the sea in relation to one another. The questions raised have still not been altogether settled, but investigations carried out since Nansen's day would appear to indicate that certain aspects of this theory as to how these shelves originated require some amendment. In this inquiries into these and other matters Nansen touched upon aspects of geology. One authority on the subject, W. Werenskiold, has declared that although geology was not Nansen's true field, he succeeded in mastering so much of it that he might have been studying geology all his life.

MODERNIZING THE TECHNIQUES OF RESEARCH

The thoroughness which characterized Nansen's activities from childhood caused him to apply himself far more intensively to the tasks confronting him than was the case with the majority of his fellows. He realized that if physical oceanography was to make progress it was essential to demand a great deal more precision than had hitherto been deemed necessary. He set about improving instrumental methods and introduced many new designs relating to such things as water samplers, thermometers, current meters, aerometers, and plankton nets. In the rapid expansion that has since taken place in the field of oceanography the accuracy of the methods employed has been of immense importance; Nansen was altogether one of the foremost pioneers of modern oceanography.

Nansen attended as one of Norway's representatives the conferences which were held around the turn of the century to establish international co-operation in North European waters. An international oceanography office was opened in Copenhagen and for many years Nansen was a member. At his suggestion a central laboratory was set up; Oslo was chosen as the site and Nansen himself appointed head. The laboratory commenced its activities in 1902, with Dr. Ekman and the English chemist Charles Fox as assistants. Nansen did a great deal of work in this laboratory on the technique of oceanography, and basic measurements were made of certain important physical and chemical conditions. The laboratory completed its assignments in the course of a few years, whereupon it was closed down.

In the summer of 1900 Nansen took part in the first voyage made by the

Government survey ship *Michael Sars* to the Norwegian Sea, an expedition led by Dr. Johan Hjort. This trip presented Nansen with an opportunity to test various new instruments under field conditions and to study the effect of the enhanced precision in working methods he had already helped to bring about. He published a personal account of this voyage in *Nyt Magasin for Naturvidenskaberne* (The New Natural Science Magazine) in 1901. Such scientific expeditions to the Norwegian Sea on board the *Michael Sars* and other vessels were continued during the next few years. The material gathered on these voyages between 1900 and 1905 was collated by Nansen, in collaboration with Bjørn Helland-Hansen, and the results published in a monograph under the title *The Norwegian Sea (Report on Norwegian Fishery and Marine Investigations*, Vol. II, No. 2) (Bergen, 1909). The increased accuracy that typified these observations compared with those that had been possible using the old methods led to a new concept of various marine conditions. Among other things it was proved that the waters are practically always composed of stable layers, the density increasing with the depth. Previously held views on ocean currents had to be revised. It was found that there must be unforeseen circulatory movements in the sea and the supposition that there might be considerable internal waves in the water masses of the intermediate layers was strengthened. It was probable that the alternations that occurred at intervals in the currents, and notably in the offshoot of the Gulf Stream which thrust its way into the Norwegian Sea, were considerable; this applied *inter alia* to the changes which occurred from one year to another. This posed a variety of problems, but though a great deal of attention has since been devoted to them, they have still not been altogether solved.

Nansen took part in a number of other oceanographic expeditions, too. At his request the gun-boat *Frithjof* was despatched to the north-east Atlantic in the summer of 1910, to enable him to undertake oceanographic investigations in those waters. He published his findings in 1913 under the title *The Waters of the North-Eastern North Atlantic*. In this work he came to a conclusion in regard to the general circulatory system in the eastern part of the North Atlantic which differed in large measure from the accepted theory. Formerly it had been thought that the waters of the Gulf Stream off Southern Europe flowed southwards, but Nansen claimed that this applied only to a relatively shallow surface layer, the bulk of the water lower down flowing eastwards past Madeira and northwards off the coast of Portugal, not southwards. Oceanographers of the time were reluctant to accept Nansen's theory, however. The matter is of vital importance to a complete understanding of the North Atlantic as a whole, and in order that it might be studied more closely a research ship, the *Armauer Hansen*, was despatched on a second expedition, of which Nansen was again a member. The results of this expedition were published by Nansen and Helland-Hansen in a paper entitled *The Eastern North Atlantic* in 1926. Admittedly the currents charts at varying depths differed considerably

from the chart published by Nansen in 1913, but the main principle proved to be correct, as was later verified by direct measurements undertaken by an expedition which sailed on the *Armauer Hansen* in 1930.

Nansen drew up the plans for the investigations made by Roald Amundsen in 1901 on a proving voyage in the *Gjøa* to the Barents Sea and the northern part of the Norwegian Sea. The observations made were published in an important work, *Northern Waters* (1906), in which Nansen discussed among other things the question of the origin of the deeps (the bottom waters) in the northern seas. In a work published in 1912, *Das Bodenwasser und die Abkühlung des Meeres*, Nansen dealt in more general terms with the question of the formation of the vast masses of cold water to be found in the depths of the major oceans. His principal conclusion was that the water at the bottom of the sea is formed by a cooling and sinking of the surface water in the winter in certain specific areas. The bottom water of the Norwegian Sea and the Polar Sea originates in an area north-east of Jan Mayen and that of the north Atlantic in an area south of Greenland.

In 1912 Nansen sailed in northern waters himself, on board his small yacht *Veslemøy*, his objective this time being the waters west and north of Spitsbergen. He hoped to be able to sail sufficiently far to the north of Spitsbergen to enable him to carry out investigations in the deep layers of water in the Polar Sea, to check the observations made by the *Fram*; but the state of the ice prevented him from penetrating north of the shelf. Apart from this, however, the expedition achieved good results, an account of its findings being published in 1920 under the title of *Spitsbergen Waters*. Other expeditions later succeeded in making observations in the deep Polar Sea north of Spitsbergen and it was found that the temperatures recorded coincided almost exactly with those measured by the *Fram* expedition and corrected by Nansen.

In their monograph *The Norwegian Sea* (1909), to which reference has already been made, Nansen and Helland-Hansen raised the question of a convection effect involving the ocean and the atmosphere. Later they re-applied themselves to this problem on a broad basis and published a lengthy treatise on temperature changes in the Atlantic Ocean and in the atmosphere; this work came out in German, in 1917, a revised and enlarged edition in English being published in 1920. Some years later Nansen published two more works on climatic changes, *Climatic Changes in the History of the North* (1925) and *Climatic Changes in Historical and Postglacial Times* (1926).

THE HISTORIAN OF DISCOVERY

In yet another field Nansen made an outstanding contribution to scientific literature. He once received a request to write a chapter on the history of polar exploration for inclusion in a big English work. The article in question was destined never to be completed, however, because as soon as he set to work,

the vastness of the subject was borne upon him and he realized that if he was to do it justice and produce an article to his own satisfaction, it would inevitably exceed the space allotted. Instead he turned his pen to the writing of his great book *Nord i Täkeheimen* (In Northern Mists), which was published in 1911 and which deals with the exploration of the Northern regions from the earliest times to the voyages of Corte-Real around A.D. 1500. This work has proved fundamental to students of the history of exploration. In an extensive account (September 1939) of the position of geography and the tasks confronting it in Norway, Dr. W. Evers, the German geographer, declared that in *Nord i Täkeheimen* Nansen had rendered a masterly account of Norway's first appearance on the stage of world history. 'The reason why we chose to begin our account with this work is in the first place because it is based on authoritative knowledge, as no one has been better qualified to describe the discovery and exploration of the northern territories and seas than Nansen; but in the second place, not only geographical science in Norway, but science the world over, owes Nansen, researcher and explorer, infinitely much. Any appraisement of geography in Norway must, therefore, in my opinion, inevitably take Norway's greatest son—in scientific and human respects alike—as the central figure.'

As has been said, Nansen was irresistibly drawn to the polar regions. 'The call of the wild', he declared in his St. Andrews address, 'is vibrating under all our actions, making life deeper higher and nobler.' He concluded the address by quoting from one of his favourite poets, Robert Service, on feeling the great white stillness and listening to the call of the wide open spaces. He had long contemplated making a voyage to the South Pole. Before setting out with the *Fram*, in 1893, he announced his intention of organizing an expedition to the South Pole on his return. However, when the time came he found himself so involved in other work that his plans in that direction had to be postponed. When he took up his ministerial appointment in London in 1906 he assumed that it would be only for a year, and continued with his preparations for an attempt on the South Pole. When Roald Amundsen approached him to inquire whether he might borrow the *Fram* for an expedition to the North Pole, Nansen replied that he was himself thinking of taking the vessel to the South Pole. But some months later he gave up this project and lent the *Fram* to Amundsen, who wished to sail round Cape Horn and up through the Bering Strait. When news was received that Amundsen first intended to try for the South Pole, Nansen was considerably taken aback, but nonetheless loyally supported Amundsen's decision and backed him to the hilt.

In 1913 an opportunity arose for Nansen to make another trip to the Arctic, as the Siberia Company wished to explore the possibility of transporting cargoes by sea from the estuary of the Yenisei in Siberia. An attempt made in 1912 had proved unsuccessful, but it had been resolved to make a second attempt with another ship, the *Correct*. The company's board of directors invited Nansen to take part in the voyage, which took the ship through the

Kara Sea, where Nansen helped to find a passage through the ice. Sometimes he was able to act as look-out from the crow's nest, a task which gave him considerable pleasure. The expedition reached its destination without mishap and the success of the undertaking was thus assured. Nansen then accepted an invitation from the Russian authorities to proceed right across Siberia to Amur, returning via Russia. Nansen has given a full account of this journey in his book *Gjennem Sibirien* (Through Siberia), which was published in the autumn of 1914.

Nansen was a master of the art of writing travel books: he was able to express his thoughts and emotions in a forceful and beautiful personal prose and to paint vivid word-pictures of nature. But at the same time his traveller's tales were valuable works of popular science. With an ability that was truly astonishing he was able to describe and explain many of the works of nature and of man in a manner which was both entertaining and instructive. In later years he published a number of such books. *En ferd til Spitsbergen* (A Journey to Spitsbergen), which came out in 1920, is an account of the voyage of the *Veslemøy* in 1912; this was followed in 1924 by a book on his first voyage to the Arctic Ocean, in the *Viking*, published under the title *Blandt sel og bjørn* (Among Seal and Bear). After his extensive travels in the cause of international relief work he wrote *Gjennem Armenia* (Through Armenia) (1927) and *Gjennem Kaukasus til Volga* (Through the Caucasus to the Volga) (1929).

Nansen's literary output, both purely scientific and popular, was extraordinarily great and covered a wide range of subjects. In addition to the many publications to which reference has already been made, he wrote a variety of shorter articles for scientific journals, magazines, and the daily papers. This prolific output is all the more imposing when one calls to mind Nansen's many other activities and the restless pattern of life that was the inevitable outcome of his many travels. He was however afforded a great deal of help by the diaries he never failed to keep, often under difficult and trying conditions. Nansen's motto was ever, 'Improve the shining hour'.

Despite his multifarious commitments Nansen was occasionally able to snatch a few moments of leisure and these he largely devoted to sketching and painting. He was a very capable artist and when, as a young man, he was in Bergen, the painter Schiertz urged him to give up his scientific studies in favour of art. Later in his career Nansen's draughtsmanship was strongly influenced by a close friend, the Norwegian artist Erik Werenskiold. Nansen illustrated many of his books himself and was responsible for most of the graphical representations that form a part of his scientific works.

WHERE HONOUR IS DUE

But Nansen was no Aladdin, able to get things done with a modicum of effort. He did not work easily and smoothly, but applied to the task in hand all

his exceptional capacity for hard work and his unusual strength of will. He possessed strong powers of self-discipline and was frequently compelled to apply these powers to subjugate his own inclinations and desires, or to overcome the weariness and lassitude that occasionally crept over him. Real difficulties or dangers, however, merely served to spur him on to still greater effort. In his 'off' moments he was at times dissatisfied with himself: his early diaries, for example, contain several expressions of doubt as to whether his life would not have been better employed had he focused his energies in one direction, instead of dispersing them over so many varied fields. He wished, in particular, that he might concentrate on scientific research. A strong sense of obligation and responsibility drove him to undertake new assignments, with the result that in the meantime his scientific interests had to be shelved. Time and again work of a political or humanitarian nature, each new task more formidable than the last, made calls upon this time and abilities.

Throughout these hectic years Nansen's fame as one of the great figures of his age continued to grow, and his authority, both in Norway and abroad, became still greater. In 1922 he was awarded the Nobel Prize for Peace, and rarely has the choice of recipient been so universally applauded. A Danish publisher, Christian Erichsen, doubled the prize-money. All this money was devoted to the cause of international relief, what was left at Nansen's death being transferred to the Fridtjof Nansen Memorial Fund, which was set up at the instigation of prominent statesmen in a number of West European countries, an appeal being launched for worldwide contributions to aid the refugees. Characteristic of the admiration in which Nansen was held abroad was the decision of the students of St. Andrews University in Scotland to appoint him Lord Rector. It was here that he gave the inaugural address on the spirit of adventure, touching upon certain aspects of the progress of mankind and civilization, and illustrating his points by examples drawn from his own crowded life. This inspiring speech in many ways constitutes Nansen's spiritual testament. Prior to his St. Andrews appointment Nansen had been made an honorary Doctor of Science at Cambridge University and Doctor of Civil Law at Oxford.

HEALING THE SCARS OF WAR

Despite his fame as a polar explorer and scientific observer Nansen's greatest claim to world recognition rests on his representation of Norway at the League of Nations and his wide-scale humanitarian work. From being Norway's hero he became the world's, thanks to his unsparing efforts in the cause of peace, his unrelenting struggle against the doctrine of aggression, his alleviation of the sufferings left by war, and his all-embracing, wearing endeavours, when all thoughts of self were thrust ruthlessly aside, to save his less fortunate fellows from starvation, exile, and despair. World War I made a terrible

impression on Nansen, as is apparent from his writings in *Friluftsliv* (Outdoor Life) (1923) and *The Red Horizon*, the latter jottings written in the United States in 1918. He doubted whether any good would come of the war, maintaining that victory breeds hate and that everlasting peace cannot be achieved through the use of armed force. His principal task became to persuade the peoples of the world to lay down their arms in a figurative sense—to *think* peace—so that war would become redundant and an impossibility. 'A renaissance must take place,' he wrote in 1916, 'a new era with new ideals, in which spiritual values will again become ends in themselves and the material only means; when the mob and the mediocre will no longer rule the world, but great men will lead mankind towards higher things.'

EARLY SUPPORT OF THE LEAGUE OF NATIONS

In October 1918 Nansen was elected chairman of the Norwegian League of Nations Society, which had been founded at the urging of Dr. Wilhelm Keilhaus, and he threw himself wholeheartedly into the many discussions that were held among the members of the committee on the question of how a League of Nations ought to be organized. In February 1919 he went to England to present Norway's views on the projected League. There he had talks with leading politicians and made the main speech at a big banquet arranged by the British League of Nations Society in the Criterion Hall. Afterwards he attended the Peace Conference in Paris and continued to make his views known. Everywhere his opinions were listened to with respect. As Lord Curzon, then the British Foreign Minister, later declared, Nansen was the only living being for whom all the doors in every government office in Europe stood wide open. To Nansen must go much of the credit for gaining last-minute permission for neutral countries to express their views on the plans for a League of Nations. Owing to the strained relations that existed between himself and a leading Norwegian politician, Nansen was not appointed a member of the Norwegian delegation, but nevertheless he did a great deal behind the scenes to propagate the Norwegian ideas through the medium of his own considerable personal influence and his many friends and acquaintances.

At the same time he strongly advocated a definite line of policy with regard to Russia. His expressed view was that the Western powers ought to leave Russia to sort out her own politics free from outside interference, and that military intervention should not be attempted.

On the other hand he was firmly in favour of extending aid to Russia, where hardship and privation were already rife. This idea was first and foremost President Wilson's. When in March 1919 Wilson returned to Paris, he asked Herbert Hoover to prepare a memorandum on the Soviet problem. In his book *The Ordeal of Woodrow Wilson* Hoover relates how in this memorandum (dated 28 March 1919) he proposed that 'some neutral of international reputa-

tion for probity and ability should be allowed to create a second Belgian Relief for Russia', and continued: 'He should ask the Northern neutrals, who are specially interested both politically and financially in the restoration of better conditions in Russia to give him diplomatic, financial and transportation support.'

The man he had in mind was Fridtjof Nansen, with whom he had had dealings in the United States in 1917 regarding the shipment of supplies to Norway and for whom he cherished warm friendship and admiration. Hence Hoover was the man who approached Nansen and put the plan to him in broad outline. After having pondered the matter for a short while Nansen agreed to organise the work. On 3 April 1919 he sent a letter to the Big Four of the time—Wilson, Clemenceau, Lloyd George, and Orlando—proposing to set up a commission for carrying out the plan. This letter is reproduced in Nansen's book *Rusland og freden* (Russia and the Peace), which was published in 1923. On 9 April the Supreme Council declared itself favourably disposed towards the scheme, provided that all hostilities in Russia ceased. After innumerable difficulties and violent opposiiton, both from Russian emigrés in Paris and from a number of the governments represented by the Supreme Council, Nansen succeeded in early May in despatching a telegram to the Soviet Union's Commissioner for Foreign Affairs, Chicherin, who rejected the offer on the ground that it constituted camouflaged intervention. The Soviet Government was willing to negotiate for peace, but politics had to be kept apart from humanitarian activities. It was prepared to send representatives to a metting abroad with Nansen and his colleagues to discuss the latter question. Nansen on his part was willing to journey to Russia to negotiate, but the whole scheme fell through as there was no indication that the Supreme Council would waive its conditions. Disappointed, Nansen returned to Norway in May and resumed his scientific work; but he was unable to relinquish the thought of helping to heal the scars of war. On 20 December 1919 he issued an appeal, in which he urged that Norwegian families, too, should adopt children from the starving countries of Central Europe.

REPATRIATION OF PRISONERS OF WAR

In the spring of 1920 Nansen cut off his own line of retreat for ever, when he threw himself heart and soul into the task of conciliation. In February of that year the Allies' Supreme Economic Council in Paris approached the Council of the League of Nations with a request that a start might be made with the repatriation of prisoners of war from areas under Russian control. This was one of the most crucial and difficult of the post-war problems, and one which had been aggravated by the Revolution and civil war that had occurred in Russia. In Siberia, the Urals, the Caucasus, and Turkestan there still remained several hundred thousand prisoners of war who were suffering agonies of

hardship and privation. In Central Europe an equally large number of prisoners awaited repatriation. They were free to return to their own countries, but lacked the funds, the strength, and the transport to do so. In Siberia conditions were so appalling that it was feared that many of the prisoners would die of starvation or exposure during the winter of 1920-21. With the cessation of hostilities the various Red Cross organizations and the International Red Cross Committee had continued the work on behalf of the prisoners of war, but the task was too much for them alone. The attempt of the Allies in 1919 to aid the prisoners likewise proved abortive. The governments of the countries to which the prisoners of war belonged were so impoverished as a result of the war that they were not in a position to bear the costs of repatriating their fellow countrymen, a task which was made still more difficult by the state into which communications had fallen.

The only solution was international co-operation on the part of all the nations involved. In March, the Association of Red Cross Societies also approached the League of Nations Council and as a consequence the Council resolved to take upon itself the task of repatriating *all* prisoners of war, not only those in Russian hands. The Council was not able to take any direct measures itself, but declared that the only way the technical and financial difficulties could be overcome was to entrust to a person publicly esteemed for his organizing ability, forcefulness, natural talents, and breadth of vision the task of deciding what is most needed and pressing. What was wanted was an intermediary between the world powers, so that they might be brought to the conference table to negotiate. It was a tremendous, almost superhuman task, as the Council was unable to say where the prisoners were, where money, clothing, and transport could be obtained, and whether Soviet Russia would be prepared to render assistance.

At the suggestion of a young English secretary, Philip Noel Baker, who was to become Nansen's faithful companion and helpmate, the Council sent a telegram to Nansen, asking him to accept the post of High Commissioner to the League of Nations; but Nansen turned the request down because of the scientific work on which he was engaged. The Council refused to accept defeat and sent Noel Baker to Oslo, where, on 11 April, at a meeting in his own home at Lysaker, near the capital, Nansen agreed to accept the assignment. In so doing he fully realized the extent of the sacrifice he was making and the risk involved. He knew, too, what difficulties confronted him, and foresaw that months would be required to complete the work: but he felt it was his duty to answer the call and from that time on he was a servant of humanity. He was impelled not merely by sympathy for the suffering masses, but also by a strong sense of the fateful disturbance in the equilibrium of Europe stemming from the exclusion of Russia. His determining motive was to show the world that the League of Nations could solve these problems, thereby creating a firm foundation of confidence and faith in the organization

and making it a conciliatory factor, dedicated to erasing the aftermath of hate and bitterness left by the War.

Nansen's zeal, coupled with his organizing ability and the confidence that one and all placed in his integrity and unsullied character, served to overcome what had at first appeared to be insuperable obstacles. He overcame the distrust of the Soviet authorities and re-established relations with that country, not, in this case, as a representative of the League of Nations but on behalf of the individual governments involved, and brought about an agreement regarding exchange of prisoners. He prevailed upon the governments to co-operate with one another, often having himself to act as go-between; was ever dashing hither and thither to negotiate, supervise, and organize relief work in different countries; set up in Kovno the Central Organisation's Nansen Relief, whose task it was to work together with all other relief organizations; and established distribution centres for food, clothing, footwear, and medical supplies.

The International Red Cross afforded invaluable assistance. Nevertheless he appealed to the Americans for further aid and monetary assistance. He succeeded in raising money or credit, which was the hardest of the many difficult tasks facing him. Seven countries, among them his own, combined to raise a credit of 425,000 pounds sterling. At his suggestion the League of Nations arranged for the first time an international loan for countries which were themselves unable to raise funds.

Despite the crisis that existed in the shipping industry, Nansen managed to acquire a number of ships, among them 14 German vessels. Then, in May 1920, he turned to the job of transporting the luckless exiles overland to the Baltic along a route already mapped out by the Red Cross, or to the Black Sea, or, at a later stage, through Siberia to Vladivostok, there to travel by ship, and again by train, until they reached their homes. In this work the American Red Cross played a decisive part.

Nansen succeeded in arranging an exchange of Greek and Bulgarian prisoners in the Balkans, where the difficulties were formidable. In 1922 he journeyed to Constantinople, and there negotiated the exchange of Greek and Turkish prisoners of war. In the course of 1920-21 no less than 447,604 prisoners of war from 26 countries were liberated after many years in wretched conditions. This work took 18 months and was brilliantly and incredibly cheaply organized by Nansen.

The League of Nations had acquitted itself well in the first task it had chosen to undertake, and in consequence its prestige was greatly enhanced. In his first report, dated November 1920, Nansen wrote that what, above all else, this work had taught him, was that it must be a primary object of the League of Nations at all times to prevent a recurrence of such catastrophic conditions, which must inevitably result in dreadful sufferings for mankind.

THE REFUGEE PROBLEM

Even before he had submitted his first report Nansen had taken on a fresh assignment, one on which he was to work throughout the remainder of his life and one which was still nowhere near solution as late as 1939, when World War II broke out. In February 1921 the International Red Cross asked the Council of the League of Nations to nominate a High Commissioner to assume responsibility for the one and a half million Russian refugees, who, after the Revolution and the civil war that followed, were dispersed throughout Europe and Asia, and whose maintenance was costing untold sums of money. To add to the problem, there were several million refugees of other nationalities, living in the direst need and misery, without employment and means of subsistence, and hounded from country to country. What was required was to provide them with food and to transport them to places where they could support themselves. The Council gave its approval to the scheme in June, and in August urged Nansen to accept the post of High Commissioner, to arrange for co-operation among the governments concerned and the various privately run relief organizations. Two conferences between representatives of the governments interested were held in Geneva in August and September 1921. The second conference, at which 13 nations were represented, was presided over by Nansen himself, and it was there that the general principles on which the work was to be carried out were agreed upon.

Nansen immediately set about the task of taking a census of the number of refugees involved and the kind of work they could do, but many of the Russian emigrés, who nurtured a bitter hatred of the Soviet government, resisted his efforts and hampered him at every turn. His original plan to get many of them back to Russia did not succeed. He approached the various governments concerned, but many of them refused to comply with his wishes: they were afraid of the Russians and the crises within their own borders made it difficult for them to find employment for the refugees. Eventually he managed to get the governments of 16 countries to appoint representatives with whom his own representatives could negotiate. He himself had representatives in 15 countries, and offices which looked after the interests of the refugees and assisted them in making their way to countries where they would be given work. In Constantinople, in particular, the refugee problem was very pressing. At the same time Nansen sought to co-operate with European and American relief organizations, which provided the refugees with food, and with women's organizations, particularly in Scandinavia, and arranged for the setting up of a committee whose task it was to bring about collaboration between American, European, Russian, and Jewish organizations. The funds at his disposal were limited: as he pointed out in 1922, had he but had more money to spare, he could have achieved results of quite different proportions. In fact, he had to make inroads on a good deal of the money presented to him by the

Danish publisher Christian Erichsen in connexion with his Peace Prize award, to support the Russians of Wrangel's army in Constantinople, who were literally starving. Dogged and untiring, he gradually began to make headway, after a great deal of travelling and negotiating, in persuading the governments to help the refugees, to accept them, and to facilitate their movement.

THE NANSEN PASSPORT

One of the worst problems confronting him was that the stateless Russian refugees possessed neither passports nor identification papers. It was then that Nansen hit upon a solution that was unique in the history of the world; to be known as the Nansen Passport, it was a certificate of identity, which he then proceeded to get approved at an international conference at government level in 1922. He managed to get this passport recognized by no less than 52 governments, who were also prepared to waive certain visa formalities. Later, Armenian, Chaldean, Syrian, and Turkish refugees were also furnished with such passports. The money derived from sale of these passports (they cost 5 francs and had to be renewed annually), together with the revenue from a special Nansen postage-stamp, he devoted to aiding the unemployed and needy refugees. In order to improve their lot Nansen had to establish yet another international organization, this time an international employment agency for refugees, in collaboration with the International Labour Organisation, which in 1924, once the political difficulties had been surmounted, took over the work, though still maintaining its contact with Nansen. In 1928 the work of helping the refugees was once again transferred to Nansen's broad shoulders, after the League of Nations, in 1927, had resolved to extend its relief work to include other refugees besides Russians and Armenians, namely the Assyrians and Assyrian-Chaldeans.

Several governments expressed their opinion that the refugee problem must not be allowed to become permanent, and put difficulties in the way of Nansen and his associates, so much so that in 1929 Nansen was compelled, by threatening to resign from his post, to force the League of Nations to continue the work for a further 10 years. Nansen then resumed his activities, and planned, among other things, agricultural colonies for 63,000 refugees. After his death the work was split up, the political and juridical side being allotted to the League of Nations Secretariat, the humanitarian interests being set apart and made the province of an office under the control of the League, Nansen's International Office for Refugees; this office was reorganized in 1958 and its activities transferred to London.

FAMINE RELIEF IN RUSSIA

In August 1921—at the same time as the League of Nations Council put forward its request for help to the refugees—the International Committee of

the Red Cross urged Nansen to take charge of a campaign to relieve the starvation then rampant in Russia. The Russian famine, which Nansen had foreseen in 1919 and which was particularly acute along the Volga and in the Ukraine, constitutes one of the greatest disasters of modern times and took toll of millions of human lives. Those who did not die of starvation fell to the ravages of cholera, spotted typhus, and other infections; and a shortage of seed-grain threatened to cause still greater suffering. When Maxim Gorki approached him in July 1921, Nansen arranged for several hundred tons of salted fish to be despatched to Petrograd and obtained a promise from the Norwegian Government of more. He hoped that this was all that would be required of him. Later in the same month he received another request, however this time from the Secretary-General of La Commission Internationale des Crédits de Relèvement Économique in Paris. Under the leadership of Herbert Hoover the American Relief Organization had taken steps to counter the threat of starvation, and from 1921 to 1923 this organization did a magnificent job—though it must not be forgotten that it had considerable funds at its disposal.

When Nansen received this new request he became very downcast. If he were to accept this post as High Commissioner of the Red Cross Societies it would be tantamount to giving up his scientific work for ever; and he had just planned an expedition to Asia. But he did not have the heart to say no, and on 12 August he threw himself into this new task with his customary energy and enthusiasm. He was to take over the relief work from Europe and Hoover that from the United States. He drew on his own funds, travelling third-class and staying at cheap hotels, hoping that as many lives as possible might be saved. He hurried immediately via Berlin to Riga, where he met Litvinov, but the negotiations that ensued did not turn out as had been hoped, so he journeyed on to Moscow. On 27 August he came to two agreements with Chicherin, whose confidence he enjoyed. One of these agreements was to the effect that a committee should be set up in Moscow, to be known as the International Russian Relief Executive, the office of which, together with a similar office in Berlin, should be administered from the Central Office of the Nansen Mission in Geneva. The Moscow Committee comprised one representative of Nansen and one of the Soviet Government and had sole right to determine how the supplies sent to Russia should be distributed. The Soviet Government undertook to transport relief supplies free of charge in Russia under the auspices of the committee.

The second agreement was to the effect that Nansen, in the name of the Soviet Government, should ask the governments of other European countries for a credit of 10 million pounds sterling, five million for immediate use and five million for the work of reconstruction and rehabilitation. He then attended the Assembly of the League of Nations as chairman of the Norwegian delegation, and made repeated attempts to obtain assistance; but here he came up

against a stone wall. The Soviet Government was regarded with mistrust. No-one believed that it would honour its pledge to provide transport and arrange for distribution of supplies, and Nansen was severely criticized. In certain quarters scurrilous lies were set on foot during these years, to hamper the work of relief, and thus tremendous difficulties were repeatedly encountered. Nansen fought bravely in the League of Nations for his beliefs, addressing the Assembly on 9 September, the Sixth Commission on 27 September, and the Assembly once again on 30 September. He urged the delegates to the Assembly to ask their governments to put up credit to the extent of five million pounds sterling, in the process appealing to them, pointing out their great responsibility, and even going so far as to accuse them. There was no time to lose; it was a race with the dread Russian winter. He implored them: Save Russia! Hurry up and do something before it is too late for anything but regrets! This impassioned speech, which was greeted with a storm of applause from the galleries, was followed by a heated debate, and Nansen lost. The Assembly expressed its admiration for all Nansen had accomplished, and urged private citizens to help him, but refused to approach their governments. Further action in the matter was left to a conference held in Brussels on 6 October, at which it was resolved to drop the scheme altogether.

Let down by the politicians, Nansen turned to ordinary people the world over: but first he had to organize the work, purchase supplies, and establish contact and co-operation with various organizations and associations and with the regional officers in Russia. In September the first trainload of grain left for the East, and during November and December Nansen himself visited Russia on a tour of inspection, travelling in the starving districts near the Volga at the risk of his life; in fact, a number of his colleagues died of typhus. Nansen was a changed man when he returned: the horrors he had witnessed had made an indelible impression on his mind. From January 1922 and on through the spring he gave hundreds of talks to capacity audiences in Europe and America, and the rank and file of the people responded generously to his earnest appeal. Considerable sums of money were raised in this manner and many governments contributed to the fund; but even so it was not enough. In March 1922 he sent to the President of the League of Nations, via the Norwegian Government, a memorandum suggesting that an impartial survey should be made and personally attended the meeting of the Council on 16 May at which his proposal was scheduled for discussion. It was agreed that information on conditions in Russia should be compiled, but on 29 January 1923 the Council decided that a Committee of Enquiry would not be set up after all; by that time the worst distress was a thing of the past.

From September 1921 to August 1923 the Nansen Mission continued its magnificent work: it was unable to help all those who were in need, as it did not receive the wherewithal in time, but none the less succeeded in saving the lives of 6,400,000 children and 400,000 adults. Nansen visited Moscow in the

late autumn of 1922 to confer with those in charge of this work, and in January he journeyed to Kharkov, where relief work was in the hands of Vidkun Quisling. Nansen did not aim merely to alleviate the immediate suffering and want, but also to help the distressed people to help themselves. Consequently he despatched not only food and medical supplies, but also tools and machinery, tractors, horses, fodder, and seed-grain, the plan being that the peasants should pay for these things when they had re-established themselves on a sound footing.

In the autumn of 1922, as we have already seen, Nansen's self-sacrificing work on behalf of the refugees was publicly recognized, the Nobel Committee of the Norwegian Storting awarding him the Nobel Peace Prize, and the sum this represented being doubled by the Danish publisher Christian Erichsen. In July 1923, using some of the Nobel prize-money, Nansen set up two large agricultural stations, which the Soviet Government took over in 1927. He now commenced to widen his activities to embrace a broader front, providing schools and universities with books, instruments, and educational equipment, and endeavouring to help the cause of Russian scientific research to the best of his ability. In 1922 Nansen opened two information offices, one in Geneva, the other in Moscow, their aim being to compile objective reports on conditions inside Russia—conditions which he himself described in his highly controversial book *Rusland og freden* (Russia and the Peace). Despite all the criticism that has been levelled at his work, there can be little doubt that without the personal intervention of Fridtjof Nansen it would have been impossible to have rendered effective aid to Russia. The Russians themselves idolized him: as a Russian doctor once put it, 'the name of Nansen is written in the stars right across Russia'.

NEW HOMES FOR GREEK REFUGEES

While Nansen was engaged with all the resources at his command in the immense task of bringing aid to devastated Russia, a fresh call for help reached him. In the autumn of 1922 the Turks defeated the Greeks, and the entire Greek population of Thrace and Asia-Minor was forced to flee. These countries had been their ancestral home for thousands of years, but at a moment's notice they were compelled to leave everything—hearth and home, farms and cattle, all their goods and chattels; only those from Thrace were able to take any of their belongings with them. Greece, their original homeland, suddenly found herself with a million extra mouths to feed. Nansen received telegrams from his representative in Constantinople and from the Greek Government, while he was in Geneva.

The matter was of such urgency that he managed to persuade the League of Nations to carry out the required procedure of convention and committee work in the course of a single day. He was authorized to undertake relief work

and the Assembly made a grant of 100,000 francs; a number of governments, headed by the British, made large sums of money available, and in the brief span of one day tons of food had been purchased and ships chartered. A few days later the first supplies reached the distressed populations. On 30 September Nansen himself went to Macedonia to organize the international emergency measures. He first visited Belgrade, then Sofia and Constantinople; with the declaration of a truce in Mudania he journeyed on through Thrace, where he witnessed the mass migration of peoples at first hand and endeavoured to end the panic and bring some semblance of order to the confused situation. He succeeded in directing transportation of the refugees, setting up camps and building huts, staving off the threat of starvation, and restricting the outbreak of epidemics.

An appeal to countries abroad brought him more money, tents, building materials, and clothing; food and temporary shelter were thus made available to the refugees, but the burning question was, what was to be done with them? It was then that Nansen hit upon the bold idea of exchanging the Turks in Greece with the Greeks in Asia-Minor and giving them land and employment—a plan which aroused considerable opposition and which was regarded as being wild and impracticable. Eventually, however, he persuaded the Greek and Turkish governments to agree to his scheme. He went to Salonika and to Athens for negotiations, and then boarded a destroyer which took him back to Constantinople, where the victorious Turks placed difficulties in his way, with the result that he achieved nothing. He went first back to Athens, then proceeded to Geneva; but it was not until the Peace Conference in Lausanne in November that he was able to get the matter settled, and even then he was not altogether satisfied with the changes that had been made and with certain details, such as the matter of reparations. Before the scheme was put into operation he experimented with 10,000 refugees in West Thrace. This pilot scheme proved practicable, but the question still remained of how he was to transplant half a million Turks and one and a quarter million Greeks, and of how an exhausted and impoverished Greece was going to absorb a 34 per cent increase in her population. Again Nansen found a way out. He proposed the granting of an international loan of 12 million pounds sterling, with surety in the refugees themselves and guarantee in the revenue of Greece. This proposal, which one of his associates, Major T. F. Johnson, designated one of the boldest in the history of finance, was to begin with met with doubt and opposition, but in the end Nansen's enthusiasm and firm conviction carried the day. The loan was over-subscribed 20 times in London. Gradually the process of exchanging populations proceeded (it was completed in 1930), and the refugees were absorbed into Greece, which now embarked upon a period of prosperity. Nansen's optimism proved to be well founded. Some 200,000 Bulgarians, who had settled in Turkey, were also found new homes.

AID FOR ARMENIA

It was while engaged on this work that Nansen came into direct contact with the Armenian problem, when 300,000 Armenian refugees crossed the frontier from Anatolia. The plight of these hapless creatures was made much worse than that of the Greeks by the fact that no nation was willing to offer them a home.

The national home they had been promised by the victors came to nought. The League of Nations had in 1920, 1921, and 1922 passed unanimous resolutions, but at the Lausanne Peace Conference not only was the clause in the Sèvres Treaty relating to a free Armenia abandoned, but the terms of the peace were agreed upon as if the Armenians did not exist. Only in the tiny republic centred on the town of Yerevan in the Soviet Union did the remnants of the Armenian people live on. Nansen's interest was caught by this question from the very outset and in 1920 he addressed the Assembly of the League of Nations in favour of making Armenia a member of the League and suggested to the Committee on Armenia that a relief expedition should be despatched; he raised the matter again in 1921. During the negotiations with the Turks regarding an exchange of populations in the autumn of 1922 he discussed with them the possibility of being given an area within the borders of Asian Turkey where the Armenians, both refugees and those still living in Anatolia, could be gathered together, but the Turks turned him down. Under his leadership the Refugees' Office provided many Armenians with a home in Syria.

In 1924 the Council of the League of Nations urged Nansen, as High Commissioner of the League, to take charge of the matter; Nansen declined, but finally consented, together with the International Labour Organisation, to see what could be done. In June 1925 he and a party of experts travelled to Athens and Constantinople, and on through Georgia to Yerevan, to study a plan for colonization. Chicherin allowed him ingress on condition that the party did not come as representatives of the League of Nations. In his book *Gjennem Armenia* (Through Armenia), published in 1927, Nansen gives a full account of this journey, the investigations that were made, and the history of the Armenian people. Everywhere he was greeted by the Armenians with deference, respect, and hope: they gave proof of their great admiration for him, feeling that Nansen was a man who really would spare no effort to redeem the promises that had been made to them and father this hapless and ill-used people. He took this problem greatly to heart and with the passage of time its hold on him grew ever stronger. 'Don't forget the Armenians', he said in Geneva the year before he died, when a Norwegian woman inquired whether there was anything particular she should bear in mind. And the most bitter disappointment of his life was that he was unable to complete his task.

In Yerevan Nansen and the experts with him decided on a small-scale plan of colonization, involving cultivation of land after draining and irrigation,

which would provide homes for at least 250,000 people and which would require a loan of one million pounds sterling. In July he left Tiflis, crossing the Caucasus to the Republic of Daghestan, where he was accompanied on his journey by the President, and continuing via Astrakhan and the Volga to Moscow, whence he returned to Norway. His book *Gjennem Kaukasus til Volga* (Through the Caucasus to the Volga), published in 1929, gives a first-class account of this journey and of the conditions obtaining at the time. In September 1925 he submitted his plan to the League of Nations, but the fact that Armenia was a part of the Soviet Union proved a stumbling-block and was used as a pretext for doing nothing. The matter was left in abeyance, but the Council and the Finance Committee did not consider the plan for financing the scheme sufficiently sound: the Soviet Union, it was objected, was unable to provide adequate security. In September 1926 the Council contented itself with expressing its sympathy and promising its support if wealthy Armenians would provide the wherewithal. Nansen cut down on his plan and its costs and approached the governments; a few promised to help, but the appeal came to nothing because the British Government refused its support. In 1927 he proposed to the Council that he should relinquish his appointment as the League of Nations was not prepared to make any sacrifices. The Council begged and expostulated, and he eventually allowed himself to be persuaded to continue; but despite this his powerful appeal to the Assembly failed to gain the support of Britain and France.

In the course of a visit to America in 1928, Nansen finally succeeded in raising sufficient funds to enable him to make a start with his scheme for colonization in Yerevan, but again disappointment awaited him, as the Soviet Government proved unwilling to be a party to the revised plan under the auspices of the League of Nations. Greatly depressed, sad at heart, and filled with indignation he announced this dismal outcome of his efforts to the League of Nations Assembly in 1929—the last Assembly he was destined to attend. He castigated the great powers in no uncertain terms for their passive attitude and proposed that the League should cease to concern itself with the matter, a proposal that was adopted. But even so he refused to give up: with characteristic firmness of purpose he declared that it was his intention to implement the Yerevan plan when the time was more auspicious. Prospects brightened shortly before his death, when he signed an agreement whereby 12,000 refugees were to be settled in Armenia.

NO SALVATION WITHOUT THE LEAGUE

From the inaugural meeting of the Assembly of the League of Nations in 1920 until right up to his death, Nansen attended the sessions of the League as chief Norwegian delegate in Geneva. In the Council Chamber he was at once the voice of Norway and of the world's conscience, a man who put the concept

of the League into practice to the full and to whom the very thought of compromise was abhorrent. 'I feel like a European and a citizen of the world', he asserted. In such matters, he opined, the small nations of the world face their greatest task. In power politics they counted for little, but as defenders of all that is right, as mediators and conciliators between hostile power blocs, as champions of a new spirit of co-operation, and of a fairer international set-up, they had much to do to improve the lot of the downtrodden peoples of the world. He sought also while working under the auspices of the League constantly to build up its organization, its prestige, and its authority, and he worked in countless ways outside his own particular province to this end. 'Without the League of Nations we can see no salvation for Europe—or for the world', he was wont to say.

Nansen was opposed to the old-fashioned methods of diplomacy, and immediately demanded proper public discussion of all issues in the Assembly, the Council, and the various committees. He was very much against the great powers being allowed a decisive vote in the affairs of the League and asserted that without the small nations there could not be a true League; he urged that the small nations should stand shoulder to shoulder, ever watchful, to safeguard the principles of the League and by their moral strength ensure increased respect for these principles. Only if this were done could there be any hope of salvation. Together with Lord Cecil he advocated from the very outset that the League should not concern itself solely with matters of secondary importance, but also with vital and thorny issues which represented a threat to the peace of the world. He concurred in Lord Cecil's declaration that for the League it was all or nothing: 'Nothing ventured, nothing gained', he contended. Nansen was fearless in taking up matters which no one else dared to touch. And when it was a case of looking after the interests of the weaker nations in the face of the great powers, he was always to the fore.

He advocated the rehabilitation of Austria and the waiving of claims for reparations; these were matters which concerned the whole world. Nansen was therefore of the opinion that during the occupation of the Ruhr it would have been better to have made use of the League of Nations. In September 1922 he tabled a motion that the League, under the terms of Article 11 of its Covenant, should intervene in the Orient and put a stop to the conflict between Turkey and Greece. The resolution to the effect that action in this matter was within the jurisdiction of the Council was unanimously adopted, Nansen receiving strong support from most of the British dominions; but no direct measures were taken, as the issue was settled at the Lausanne Conference. Nevertheless Nansen asserted that the resolution had had some effect, as it had emphasized the League's obligation to take the initiative and intervene. The proper course would have been, he said, to have allowed the League of Nations to preside over the Peace Conference.

Nansen advocated application of the same principle during the Corfu

conflict, and was strong in his contention that the Counceil was competent to act. He himself was not a member of the Council, in which Lord Cecil fought bravely, but he enjoined upon the smaller nations to take up the struggle and create a strong body of opinion in the Assembly in favour of safeguarding the provisions of the Covenant. In so doing, said Noel Baker, he saved the League. The Italian Government made representations to the Norwegian Government in regard to Nansen's conduct, but the latter government sanctioned to the full Nansen's bold endeavours to maintain the inviolability of the Covenant and the competence of the League Council in this conflict.

Nansen had always considered it wrong that Germany should be refused membership of the League, and despite bitter opposition did all he could to get her accepted. He negotiated with Count Bernstorff to this end, and when in Geneva in 1924 the British premier Ramsay MacDonald urged Germany to join, Nansen journeyed to Heiligenberg halfway through the proceedings, in order to win over the German chancellor, Marx; from that moment Germany's attitude changed. Subsequently he travelled to Berlin, where he broadcast to the German people in an attempt to break the ice. During the extraordinary meeting of the Assembly in 1926, which ended in a fiasco, it was Nansen who prevailed upon Sweden's Östen Undén to stand firm on the proposal for permanent places for Spain and Portugal. If only his advice had been heeded, Brazil might not have withdrawn from the League and Germany's entry might not have been so long delayed. At the autumn session in 1926, when Germany finally became a member, it was Nansen who rallied certain of the smaller nations against the compromise on reforming the Council and organized the resistance with youthful vigour and enthusiasm. He strongly supported the important clause in the regulations to the effect that a two-thirds majority of the Assembly could elect a new Council (a clause which the great powers wished to have amended), emerged victorious, and by his fearless and resolute conduct asserted the sovereignty of the Assembly. And again it was Nansen who in 1927 submitted the proposal from which was to spring the great arbitration agreement in respect of settlement of disputes, the General Act, which was passed in 1928 and came into effect in 1929.

In the question of mandates Nansen played a major part: every year, when the Council and the Permanent Mandates Commission had submitted their recommendations on mandates, he moved that they should be sent to the Sixth Commission for action. He himself was at all times a member of this commission. He firmly contradicted Lord Balfour, claiming that the mandatory system was not a matter for the Council alone, but also for the Assembly. It was the Assembly's right to express its views on how mandates were administered, regardless of whether or not the governments concerned were in favour. Hence his unfailing insistence upon matters relating to mandate being debated publicly. The peace of the world rested in part on this principle being adopted, he declared. This was the boldest and most novel innovation

in the entire League of Nations set-up. It constituted an expression of the very spirit of the League, and it was essential that it should be clearly defined. There were many in the Assembly, said Nansen in 1923, who thought the mandatory system might be a means by which the gravest problem could be solved—the question of the relationship between the more advanced and the more primitive peoples of the world might eventually be settled in that way. But if that were to be the case the mandates would have to be exercised under full control and in such a manner as to ensure that the welfare of the less fortunate races became the general aim. There is no doubt that he incurred the displeasure of more than one great power by his constant intervention, but nevertheless he usually managed to get his own way. Nansen it was who defended the Mandates Commission with regard to a questionnaire it had issued; and he it was who in 1923 demanded that the question of slavery should be considered: together with Lord Cecil he campaigned for the Anti-Slavery Convention in 1926 and continued to devote himself to this vital issue until his death. Consequently he was opposed to the admission of Abyssinia to the League of Nations. He put forward the convention on forced labour which was drawn up by the International Labour Organisation. He was also much concerned with the problem of disarmament, and was well aware that if the work to that end were to fail, the prestige of the League would be greatly diminished.

To the very end Nansen fought for the League of Nations, the cause of peace, and a universal feeling of solidarity among the peoples of the world. The revival of altruism, engendering in mankind belief in a new dawn, became a mission. He stressed this in his Nobel Peace Prize address, 'Peace', in 1922; in his speech 'No More War' when the Peace Prize was awarded to the men of Locarno in 1926; in his speech in Geneva as president of a preliminary meeting prior to a peace conference in 1930 attended by representatives of every religious creed; in his many lectures in Norway and elsewhere in Europe; and on his extensive lecture tours in the United States in 1923, and as representative of the World's Alliance for International Friendship through the Churches, in 1928, and 1929.

'What was outstanding about Nansen', wrote the Secretary-General of the League of Nations, Sir Eric Drummond, when Nansen died in 1930, 'was his combination of indomitable courage, inextinguishable sympathy, and practical idealism. He was a champion who never gave way and thus who never suffered defeat, an idealist who never admitted that a cause had failed, and who thus never went under.'

In February 1930 Nansen suffered a long illness following upon a severe attack of phlebitis: he had hardly commenced his convalescence when his heart gave out. Nansen was given a State funeral on 17 May 1930, a vast concourse of his fellow countrymen following him to his last resting place. His death was mourned in every corner of the land, and from abroad came countless tokens of the esteem and admiration in which he had been held.

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INSECT PEST CONTROL

by

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World population, which at present amounts to 2,500 million, increased by 250 million between 1954 and 1960. To support this ever-growing number of human beings, world food supplies must be constantly increased; yet, of the total land area of the globe—55 million square miles—only 10 per cent is used for growing food. It was calculated ten years ago that western Europe, which accounts for 3 per cent of the land surface and approximately 13 per cent of the population of the world, consumed close on one-third of the available foodstuffs. If we add the Union of Soviet Socialist Republics and North America, we find that one-third of the population has at its disposal three-quarters of the world production of foodstuffs. Asia, with almost half the world's population, secures only 17 per cent of its food.

The need for increasing food supplies is thus evident. This can be done in three different ways, either separately or in combination:

1. By increasing the area set aside for agriculture. Experts have estimated that 42 per cent of the land surface can be brought under cultivation, the rest being unsuitable for agriculture. The Soviet Union is at present using this potential on a large scale in Central Asia where millions of acres of virgin land are being turned to agricultural use.
2. By increasing yields. In many countries this can be done by modernizing traditional methods of agriculture or stock-breeding or by selecting more productive varieties.
3. By reducing losses through effective protection of crops against natural enemies of all kinds.

INSECT DAMAGE TO CROPS

Insects cause a major proportion of damage to crops, other destructive agents being rodents (rats and mice), fungi (mildew and oidium) and weeds.

The total losses thus suffered by agriculture in the United States of America in 1958 were valued at no less than $11,000 million a year, whilst in the

Soviet Union it has been calculated that effective measures against the enemies of plants could increase the value of the national agricultural output by 45,000 million roubles.

The world is teeming with millions of voracious insects. Although many species do no harm or are even useful (e.g. silkworms and bees), some of them are veritable scourges against which man is waging a ruthless war, the outcome of which still hangs in the balance. Well-known examples are the great swarms of desert locusts in Africa (the Biblical 'eighth plague of Egypt'); the invasion of phylloxera which ruined French vineyards in the nineteenth century and cost the French economy the equivalent of $6,000 million in 50 years, and the havoc wrought by cockchafers (May-bugs). At the present time the parasitic olive fruit fly is a serious menace to plantations in Mediterranean Europe, and scores of entomologists have been called in to check its depredations. The processionary caterpillar is ruining many of our forests. In the United States of America, two hours of every working day in fields, gardens and orchards are spent on feeding uninvited guests. The famine that swept through North Africa in 1866 and caused the deaths of 5 per cent of the population was due to the fact that the entire food supply had been destroyed by locusts.

INSECT-BORNE DISEASES

Not only are insects harmful to agriculture; many are also the carriers of pathogenic germs which may cause serious epidemics. Malaria, which greatly reduces the vitality of its victims, is due to the presence in the blood of a haematozoon transmitted by the bite of the Anopheles mosquito. In 1900, over seven thousand square miles of agricultural land were left uncultivated in Italy on account of malaria and even until quite recently nearly the whole population of certain areas of the world (e.g. Guiana and Malaya) lived in malaria-infested areas. It is estimated that 600 million people are afflicted with malarial diseases.

Yellow fever, also transmitted by a mosquito, used to be an endemic disease of the Panama Canal Zone. The French company which had undertaken the construction of this canal under the Second Empire failed tragically because the ranks of its workers were decimated by this disease. The American firm which took over the work started by draining the marshes in the area and yellow fever was wiped out.

Sleeping sickness, which is slowing down the development of tropical Africa and makes stock-raising an impossibility in this region, typhus and plague are further diseases transmitted by insects. Even the common housefly is all too familiar to the health worker as a carrier of tuberculosis, typhoid, etc.

It is understandable, then, that war should have been waged on insects from time immemorial. Primitive methods of destruction have now been

supplemented or replaced by modern techniques, of which there are two—the use of synthetic chemical insecticides, and biological warfare.

SYNTHETIC CHEMICAL INSECTICIDES

The idea of using toxic agents to control agricultural pests is not new. A work dating from 1681 recommends the use of arsenic derivatives to destroy ants. As early as 1854, carbon sulphide was injected into the soil in France to kill the larvae of cockchafers, phylloxera and wireworm larvae (Elateridae). More than 200 years ago, nicotine was employed to combat greenfly. Pyrethrum-powder, extracted from a kind of daisy growing in the Caucasus, was being manufactured as early as 1828.

But the stock of natural products available was rather limited and they were not always effective. It was not until the large-scale development of the chemical industry, particularly during and after the second world war, that specialists in pest control were able to draw upon a wide range of products.

CHLORINATED INSECTICIDES

The general public is most familiar with the chlorinated insecticides, particularly DDT. This product has a curious history. Its insecticidal properties were discovered in 1938 by the Swiss scientist Paul Müller, who was later to be awarded a Nobel Prize for his work in this field. Its application immediately put an end to the ravages of the Colorado beetle, which had just made its appearance in Switzerland. In 1942, a sample was sent to the United States of America, for at that time the American army was looking for a substance to replace the pyrethrum previously obtained from places then occupied by the Japanese. But German propaganda concerning the discovery of a 'nerve poison' made DDT suspect, especially as it had just been found that flies treated with DDT became convulsive. Subsequent research, however, was to show that it had no harmful effect on human beings, and the allied armies began to use it on a large scale in 1943. The results were spectacular: a typhus epidemic that had started in Yugoslavia was rapidly stamped out in Naples early in 1944. This was the first time that this dread disease had been successfully combated in winter and in time of war.

DDT is the abbreviation for the chemical name dichlore-diphenyl-trichloroethane. It is a white powder generally used in the form of a 1 to 5 per cent mixture in a neutral powder or in a solvent such as kerosene. Flies settling on any wall treated with DDT within the previous three months immediately succumb, for this substance has very low volatility and remains for a long time on any surface to which it has been applied. In other words, it is a *remanent* insecticide. Paints containing DDT in the form of microscopic

particles are now being manufactured. A bed impregnated with DDT will be lethal for bugs for 30 days after treatment.

While successful experiments were being conducted with DDT, the French scientists, Dupire and Raucourt, discovered the toxic effect on clothes-moths of the compound hexachloro-cyclohexane (HCH), more commonly known in the English-speaking countries as benzene hexachloride (BHC). English research workers, for their part, demonstrated that, of the six known isomers, only the gamma isomer had any marked insecticidal properties, whence the name gammexane now given to it. It is an insecticide used for the control of the Colorado beetle, moths, fleas, and desert locusts. Three grams of gammexane can kill a ton of locusts!

THE PHOSPHORATED INSECTICIDES

Another line of research in the development of new insecticides was followed in Germany, after 1937, under the guidance of Schrader, in the I.G. Farben laboratories. The chemicals manufactured were intended to replace nicotine, which was then used on a large scale to combat various pests but was becoming scarce. Among the phosphorated insecticides put on the market, mention should be made of parathion; it is lethal to locusts and green-fly, both of which are hardly affected by DDT. It is a poisonous liquid smelling of garlic.

At the same time, much work was done on the study of war gases, and 'nerve poisons' such as tabun, sarin and DFP (disopropyl fluorophosphate) were manufactured on a large scale though fortunately they were never used. There is a close resemblance, however, between the phosphorated insecticides and asphyxiating gases. All are derived from orthophosphoric acid or pyrophosphoric acid and act in the same way. They make up the group known as systemic insecticides, so called because of their very special mode of action to which we shall refer later. The best known of these, and the first to be developed, is schradan, named after its inventor G. Schrader and known also as pestox and OMPA (abbreviation of the chemical name octamethyl pyrophosphoramide). Other phosphorated insecticides followed in their wake, such as demeton or systox endothion, which are particularly effective against green-fly, and ronnel, which is relatively harmless to warm-blooded animals and is used in the United States of America to destroy cattle parasites.

In this category of systemic insecticides we also find derivatives of fluorine, such as DFP and sodium fluoroacetate, which is useful in combating the caterpillars of the white cabbage butterfly.

HOW INSECTICIDES WORK

The search for new and increasingly effective insecticides should not be conducted haphazardly, as was the case in the early days when the properties

of DDT and BHC were discovered. If they are to make rapid progress, research workers must have accurate theoretical knowledge of the way in which insects are killed by insecticides. Applied research is bound to benefit greatly from physiological research on insects and other animals.

Unfortunately, it is a particularly complex subject and, despite the efforts of hundreds of research workers throughout the world, we still know very little of the way in which insecticides work. We shall consider hereunder only a few of the most typical cases.

DDT. DDT is essentially a contact poison which, when deposited, can penetrate the rigid shell of insects. It has hardly any ill effect on mammals when merely deposited on the surface of their body, but if directly injected into the organism, it is equally poisonous to both mammals and insects. It is therefore thought to have a special affinity for chitin which is one of the constituents of insect shell. After penetration, DDT has a most disturbing effect on the respiratory organs and on the operation of the nervous system of the insect, which suffers severe muscular contractions and very soon dies.

In certain repects, BHC seems to be a nerve poison like DDT. Some research workers, however, have advanced another and equally plausible explanation of the way it acts. They believe that this insecticide behaves like an *antivitamin*, in other words, that it has the same effect on insects as sulfonamides on microbes.

Phosphorated insecticides. Many experiments have been carried out on mammals (mice and guinea-pigs) and insects in order to elucidate the mechanism of intoxication by organic phosphates. It is common knowlege that the nerve cells or neurons of all animals carry nerve impulses to the muscles. The nerve impulse passes from one neuron to another through the agency of acetylcholine which serves as a stimulant for the next neuron. This substance, which is fairly rapidly destroyed under normal conditions, is thought to accumulate as a result of poisoning by the phosphorated products. As with DDT, the insect suffers severe muscular contractions before dying, but these arise from a different cause.

The systemic insecticides, which have no effect in their normal state, become toxic only after being transformed by the plant which it is wished to protect against insects. These insecticides therefore have to be sprayed on the leaves or deposited in the soil where they will be absorbed by the roots. When sucking the sap, the insects will be poisoned by the toxic substances produced by the plant.

RESULTS OBTAINED

Insecticides have rapidly come into widespread use. A few examples will illustrate their present-day importance. In the United States, 150,000 tons

were produced in 1958, including 60,000 tons of DDT, 35,000 tons of BHC, 3,000 tons of parathion and 45,000 tons of other synthetic organic insecticides. Calcium arsenate, an old mineral insecticide, lags far behind, with a production of only 5,000 tons. The United States also treated 100,000 square miles of crops and orchards and 4,000 square miles of forests—in all about half the area of France. Over large areas also planes and helicopters are being used more and more extensively for spreading the substances over the vegetation that is to be protected, whether forests (in the Soviet Union and France) or great cotton plantations (United States of America).

There was a rapid response to such intensive treatment. Some crops severely attacked by parasites survived thanks only to the timely application of insecticides (e.g., cotton, potatoes and many varieties of fruit). In Tanganyika, 96 per cent of the locusts or 4,500 million insects were destroyed by spraying DNOC from the air. The dangerous coffee-bean weevil has now been controlled in East Africa by the use of DDT.

Murine typhus, a disease transmitted to man by the bite of the rat-flea, was rapidly brought under control in the United States by the large-scale use of DDT. The number of cases dropped from 5,401 in 1944 to only 131 in 1955. Cattle which have been rid of annoying parasites enjoy better health and give the farmer higher yields. Milk production in the United States rose from 440 pounds per cow a year in 1941 to about 507 pounds in 1955, i.e. an increase of 15 per cent.

A world-wide campaign for the eradication of malaria has been launched by the World Health Organization, whose 92 Member States have decided to pool their resources for the purpose. The large-scale use of DDT to control mosquitoes even in the remotest areas has meant that nearly 150 million human beings in areas that were once malaria-infested now enjoy normal health. In 85 countries and territories, the incidence of malaria dropped by 16 per cent between 1955 and 1957, and the downward trend of the scourge is continuing. The following 13 countries have achieved the most spectacular results in the matter of eradication: Italy, Netherlands, France, Hungary, Poland, Czechoslovakia, Ukraine, Byelorussia, Rumania, Spain, Portugal, the Soviet Union and Greece. Unfortunately, there are still about 56 countries in the world which have taken no action for the control of malaria. According to Dr. Alvarado, Chief of the Division of Malaria Eradication of the World Health Organization, tens of thousands of specialist teams and millions of tons of material will be needed for this campaign, while hundreds of millions of malaria victims will have to be examined.

INSECTICIDES HAVE THEIR DRAWBACKS

Have insecticides any drawbacks to counterbalance the services they have rendered mankind? What are the accidents that may be caused by their large-

scale use? Such accidents vary widely according to local circumstances. Some are very apparent, while others can be detected only after some time. These substances have given rise to phenomena similar to those attending the large-scale use of sulfonamides and antibiotics in medicine. Synthetic insecticides very rapidly came into widespread use, first for military reasons and then during the post-war period of food shortage, but the persons applying them did not receive adequate preliminary training. For many years, people were blind to the fact that these substances could not provide answers to all the problems raised by the existence of noxious insects and it was not until quite recently that this truth was brought home to them.

Disturbance of natural equilibria

The treatment of large areas, especially if no preliminary precautions have been taken, may occasionally have disastrous effects on fauna. Nature has established stable relationships between the various species in any particular environment—predators and parasites, herbivora and carnivora, etc. The action of insecticides may upset these natural equilibria and cause a rapid multiplication of the parasite which it was intended to eradicate, or of other noxious species. Entomological literature unfortunately abounds in examples of this phenomenon. For instance, the regular treatment of apple and pear orchards with DDT to control codling-moth *(Carpocapsa pomonella)* leads to the appearance of swarms of spider mites *(Tetranychidae)* and woolly aphis, as the result of the destruction by the DDT of the insects that prey on these pests. In citrus fruit orchards treated with certain organic phosphates to combat the fruit fly, we observe an abnormal increase in cochineal-insects which have a most debilitating effect on orange trees.

In the region of Dakar, a large-scale campaign was undertaken in 1946 and 1947 to get rid of fleas, since the murine typhus transmitted by these insects is endemic in the region. Before 1946, out of 30,000 fleas captured in dwellings, 93.6 per cent belonged to the species *Synosternus pallidus*; the human flea or *Pulex irritans* was hardly to be found. In 1946 and 1947 fleas had almost completely disappeared, but since 1950 they have returned in larger numbers each year, although the health service is continuing the DDT treatment. At the same time, the *Synosternus* is being superseded by the *Pulex irritans* (probably introduced from abroad) which is able to withstand DDT. Much the same thing has happened with mosquitoes. As the result of effective treatment with DDT, both species of mosquito, the *Anopheles* and the *Culex*, almost completely disappeared but the *Culex* species have now acquired a remarkable resistance to DDT. The result is disturbing from the medical standpoint for *Pulex irritans* is liable to present an even greater danger than *Synosternus* in the propagation of plague, and the *Culex* mosquito may transmit yellow fever and parasitic worms of the *Filaria* group.

Another example is equally conclusive[1]. '*Habrochila* is a bug living on the coffee bush and commonly found in the east of the Republic of the Congo (capital Leopoldville), and in Uganda. Although its depredations were seldom very extensive, many planters set about exterminating it by spraying DDT-type insecticides over large areas of coffee plantations. The result was the exact opposite of what they had hoped for. All areas treated were soon swarming with *Habrochila* causing far greater damage than before, often of catastrophic proportions.

'Thorough research was undertaken and it was found that: (1) *Habrochila* is almost completely unaffected by DDT; (2) another bug, *Apollodotus chinai*, which is carniverous, is a very active predator of *Habrochila*, destroying 10 to 15 individuals a day, for they are its chief feed. *Apollodotus* on the other hand proved to be very susceptible to DDT.

'The effect of the insecticide application was therefore to destroy the carniverous species without any abatement of the phytophagous pest. Once rid of its enemy, *Habrochila* was able to breed unchecked.'

Chemical control of forest insects is always an intricate operation on account of the great risks of upsetting natural equilibria. In Germany, for instance, the utmost importance is attached to the protection of ants which keep down numerous forest insects, many of them harmful. An American author reckoned that in 24 hours a colony of ants could capture over 100,000 insects. In Europe the little red ant, *Formica rufa*, not only destroys wood insects, but also cockchafers (May-bugs), weevils and various parasites of oak, pine and larch.

To protect forests against the ravages of insect pests, it is therefore preferable to encourage the breeding of the little red ant rather than to resort widely to insecticides.

The 'May-bug operations' during which great areas are sprayed with insecticides from aircraft or helicopters are not without their drawbacks. A large number of carnivorous insects, the importance of which is not always properly realized, are also wiped out in the process. It has recently been pointed out that their destruction seems to coincide with a sudden increase in the caterpillar population which attacks the leaves of trees. Large-scale treatment has been carried out in the Iberian peninsula to control the gipsy moth *Lymantria dispar* of which the caterpillar devours the leaves of the holm oak and cork oak. This moth has been duly exterminated, but the same treatment also destroyed the predator of a parasite known as *Tortrix irridana* which previously was not widespread but has since considerably extended its range. It is very difficult to destroy as its caterpillars live inside the oak leaves and cannot be reached by insecticides. In the meantime the oaks are still being stripped of their leaves.

1. P. Basilewsky, *Proceedings and Papers of the Fifth Technical Meeting of the International Union for the Protection of Nature*, held at Copenhagen, 25 August to 3 September 1954, p. 122.

Toxicity to domestic and wild animals

The severest effects have been observed in beehives, where the application of chemical insecticides to crops took a heavy toll of the bee population in 1946 and 1947. The most serious threat comes from the cultivation of colza, which has been greatly developed since the last war because of its economic importance. Bees were attracted in large numbers by this plant's plentiful supply of nectar and were destroyed wholesale. In some beehives at Verrières-le-Buisson, to the south of Paris, more than 2 kilograms of dead bees were found. In 1954 in the Paris region alone, 20,000 beehives were wiped out. All over the world, wherever honey-bearing flowers have been contaminated with insecticides, bees and other pollinizing insects have been poisoned wholesale.

Fish often fall victims to the insecticides used to destroy the aquatic larvae of mosquitoes and Simulium flies. The latter are small black flies which act as hosts for certain filarial worms responsible for a serious disease known as onchocercosis. To relieve the inhabitants of the Chad Zone of this scourge, the water in the region was treated from the air with BHC, fortunately over a fairly limited area. The black flies soon returned but the fish population was seriously depleted. A large-scale operation might have brought famine to the inhabitants who rely largely on fish for their food. The only effective way of controlling the black flies seems to be to get rid of their breeding places by modifying the rate of flow of the streams where they pass their developmental stage.

In the areas treated birds likely to be poisoned by the ingestion of too many insects covered with insecticides. Fledglings are most exposed to danger, especially if the doses applied have been more than normal or if the spraying has not been carefully planned beforehand. On the other hand, it has sometimes been observed that birds living in areas treated with insecticides enjoyed better health as they had been freed of their parasites.

Toxicity to man

It is common knowledge that man can be poisoned by many insecticides. The poison may be ingested accidentally with food that has been treated. It may also enter the system through the lungs: in the United States, for instance, a case was reported of 37 workers who were poisoned when handling insecticides. Penetration through the lungs is rapid and special precautions must be taken when insecticides are being applied, especially by workers using high-power machines. The following example taken from a French newspaper illustrates the point: 'A farmer was ploughing a field alongside a vineyard where a neighbour had spread a phosphoric ester to combat the grape berry moth. His horse suddenly dropped to the ground. The veterinary

surgeon was called in to attend the animal which was suffering from poisoning. The farmer too had been poisoned.'

Insecticides absorbed in small but repeated doses are accumulated in the body and some health workers allege that they must be considered as one of the causes of cancer. In the United States of America, widespread spraying with insecticides is at present blamed for the poisoning of foodstuffs which is likely to be harmful, particularly to children. This would also account for the recrudescence of hepatic diseases which in 1957 came third in the list of complaints drawn up by the medical service of the Department of State. An American research worker, M. S. Biskind, reports that, as early as 1945, it had been established that DDT is accumulated in the fat of animals, is excreted in their milk and passes into the human organism. The author states that the increased morbidity attributable to chlorinated insecticides gave rise to wide discussion among specialists. But the voices of scientists defending the interests of public health were drowned in the chorus of manufacturers anxious to sell their products and of farmers whose one thought was to increase their yield and their profits.[1]

Action on plant life and on the soil

'It would be well to bear in mind the long-term consequences of the repeated application of insecticides in the matter of soil fertility and to consider the effects of each insecticide on microflora, worms and useful entomological fauna. Lengthy and complex studies would need to be carried out for each individual substance.'[2] In fact, the soil is a highly congenial environment for the development of the fauna which abounds there in the most varied forms. Although some types are noxious, such as grubs (the larvae of the May-bug), the great bulk of them are useful. All this fauna forms a highly complex colony the members of which stand in relationship to one another and to the other biological constituents (bacteria, fungi, etc.). The very close and barely suspected links between them account for the chain reactions that may be produced when one of the factors is modified, thus speeding up or retarding the weathering processes of the soil.

The few studies that have been carried out reveal the far-reaching disturbances caused by insecticides. It is important to draw attention to the fact that the unfavourable results of treatment may not immediately show themselves in any deterioration of the productive qualities of the soil. On the contrary, the largely increased supply of nitrogen derived from the dead fauna may give the soil a new lease of life and thus conceal the longer-term

1. M.S. Biskind, 'Public Health and the New Insecticides', *American Journal of Digestive Diseases*, 20 February 1953. The present paper touches only very briefly on the subject of the toxic effects of insecticides on man. For a fuller discussion, see L. I. Medved, 'Chemical Means of Plant Protection and Problems of Hygiene', in *Impact*, Vol X (1960), No. 4.
2. R. Fabre, 'Toxicité des Produits Insecticides', *Annales des Épiphyties*, 1954, p. 177.

deleterious effects. At the present stage of our knowledge, stress should be laid on the following points:

1. The fauna plays a definite and complex role which is beneficial to agriculture.
2. The soil is the home of useful insects which may be parasites or predators of harmful species.
3. The use of insecticides for the control of crop pests leads to the destruction of much of the useful fauna to be found in the soil.

'The practical importance of these concepts should act as a brake on the indiscriminate, wholesale use of insecticides in agriculture. Insecticides should be applied only in order to control pests presenting a very serious menace. Furthermore, wider recourse should be had to methods for localized treatment (in the rows in which such crops as maize and potato are grown and through the coating of seeds with treated earth or a mixture of treated earth and fertilizer). Such methods often have the advantage of being less costly and yet almost as effective in destroying the bulk of the pests attracted by the plant. In this way it will be possible to combat crop pests while at the same time preserving the fauna which is useful for the soil.' [1]

Some insecticides are toxic to plants. For instance, farmers are recommended not to spread BHC on soil which will be planted with potatoes the following year. In a certain concentration this insecticide does more or less serious harm to the crops and makes potatoes, maize, onions, etc., smell mouldy. Tobacco, too, is seriously affected.

THE REMEDIES

In view of this long list of accusations that can be made against synthetic chemical insecticides, it is understandable that strict regulations regarding their application should have been issued, although, it must be admitted, many of them are disregarded. First and foremost, it is essential to cause the least possible disturbance to natural equilibria. For this reason, an attempt must be made to discover the insecticide which does least harm to other forms of life in the same environment. Selective insecticides destroying one species only would be the ideal remedy, but little has so far been achieved in this direction. However, one agent has been developed which is harmless to bees and enables them to get rid of their parasitic mites (Acaridae).

Measures for the protection of man must also be devised. 'Health workers responsible for the protection of public health are thus faced with problems which force them to lay down very strict regulations for the use of these products. Such restrictions on their use occasionally cause annoyance to manufacturers or users who quite honestly come to regard the attitude of

1. J. d'Aguilar, 'Influence des Pesticides sur la Faune du Sol', *Défense des Végétaux*, 1959, No. 75, pp. 1-7.

toxicologists as over-cautious. But it is the legislator's duty both to protect individuals today and to think of the generations to come.' [1]

THE RESISTANCE OF INSECTS TO INSECTICIDES

There is nothing new about the resistance of insects to insecticides. It is a phenomenon that was known in California as long ago as 1916 when cochineal-insects resistant to hydrocyanic acid made their appearance in citrus fruit orchards after cyanide fumigation had come into common use. But until the second world war, few insecticides were applied on a large scale and resistant strains were a curiosity. After the war, DDT gradually became available in large quantities and was followed by other synthetic products with remanent insecticidal properties. The widespread utilization of these substances produced spectacular effects in the case of many noxious insects, but a few years later the insects returned with renewed vigour.

The first observations regarding the resistance of flies to DDT were made in Sweden in 1946 and many cases have since been reported in Italy, Egypt, and California. Users were increasingly bitter in their complaints to manufacturers whom they accused of supplying them with inferior products. But laboratory research showed that the insects had succeeded in developing a surprising resistance. Cases are known in which this resistance is from 500 to 1,000 times greater than when DDT was first used.

The introduction of substitute insecticides such as BHC, chlordane, and dieldrin was merely a palliative, for the insects equally quickly developed resistance to them also. We know that several scores of insect species are at present resistant to insecticides and there is nothing to prove that this resistance will not become still more widespread. Flies, mosquitoes, bugs, lice and fleas are beginning to survive after huge doses. Phosphorated products and pyrethrum, an insecticide of vegetable origin, which until 1957 showed no sign of any loss of power, are now ineffective in certain cases.

In the face of this new threat, experts in the World Health Organization began to be seriously alarmed at the effects of this resistance on the control of insect-borne diseases.

It is known that resistance is a hereditary phenomenon. Insects inheriting this property are capable of breaking down the insecticide into a harmless derivative. A comparison may be drawn with the reaction of bacteria to antibiotics. A number of bacteria can speedily decompose penicillin; there are certain strains of staphylococci, for instance, which are able to withstand the therapeutic application of penicillin.

The most serious aspect of the problem is its increasing scope. Scarcely a month goes by without some new cases occurring, particularly in the field

1. R. Fabre, op. cit. L. I. Medved's article in *Impact* also discusses the regulations in force in the United States of America and the Soviet Union.

of disease-bearing insects. Our only remedy is to turn to another insecticide—and the choice is not wide. If the day comes when resistance phenomena are so universal that all substitute insecticides prove useless, it will then be necessary to fall back on the less effective but more reliable methods previously used.

BIOLOGICAL CONTROL

The second means of combating insect pests is provided by biological control, which is assuming growing importance. This is an old method, at least so far as its principles are concerned. It was first introduced by a French scientist, Boisgiraud, who in 1842 advocated the use of insects for the control of other insects, and a Russian, Mechnikov, who used bacteria to combat the grain weevil. It was mainly in North America, however, that methods of biological control came to be studied most intensively. After the second world war these methods were applied in all countries and extensive research is now being conducted in the Soviet Union and many European countries such as France and Italy.

Several international organizations are co-ordinating the work that is being done. The International Commission for Biological Control of Agricultural Pests, founded in 1956, already has 12 member countries and keeps in close touch with other countries. It publishes a review, *Entomophaga*, which deals particularly with biological pest control. Several international congresses of specialists have already been held. The European Plant Protection Organization and the FAO are also interested in the problem. The bibliography on this subject published in *Entomophaga* between 1956 and 1960 runs to over 120 pages.

Biological warfare on insect pests is waged on three different fronts: (a) by means of microbes (bacteria, viruses, microscopic fungi); (b) by means of so-called entomophagous insects, which feed on the insects to be destroyed; (c) by means of birds. In addition to these three basic lines of work, mention should be made of two other not unimportant methods: (a) selection of varieties of insect-resistant plants; and (b) the sterilization of noxious insects.

USE OF ENTOMOPHAGOUS INSECTS

One of the first and most conspicuous successes scored in this field was in the control of a dangerous parasite of citrus fruit—the Australian cochineal-insect, also known as cottony-cushion scale *(Icerya purchasi)*. This insect originates in Australia where it has never caused great damage in orchards, as its numbers are kept down by many natural enemies. But in the second half of the nineteenth century, when fruit came to be exported from Australia,

it was soon introduced to many other parts of the world. In 1868 it appeared in California and in 1890 it was detected for the first time in Europe, in Portugal. The whole of the Western Mediterranean region was soon invaded and the havoc wrought was such that in 1920 the orange trees in Algeria seemed to be covered by snow. Many fruit-farmers did not hesitate to cut down the trees, persuaded that the harm was irreparable.

As a result of the havoc wrought in California, an American mission was sent to Australia in 1889 to bring back the predators and parasites which curb the spread of the cochineal pest in its home country. Of all its natural enemies only one was finally singled out, a lady-bird *(Novius cardinalis)* which was introduced into the United States where it very readily became acclimatized and attacked all colonies of cochineal-insects. Within a few months, the orange trees were saved. The precious lady-bird has since been reared in many laboratories throughout the world to be dispatched to contaminated areas.

In this case, biological control is the only effective method now in use. Before this discovery, reliance was placed on expensive and often dangerous chemical controls, such as hydrocyanic acid fumigation of trees covered with a canvas.

The use of entomophagous insects for biological control raises a number of often baffling problems.

1. It is necessary to locate these insects and identify them very accurately—often a difficult or even impossible operation. A great number of specialists with a reliable knowledge of the various groups of insects will have to be trained. This is a long-term task, for practical experience over several years is necessary in order to identify insects accurately. The problem is a fundamental one, for if neighbouring species were confused, an insect that is completely useless or even harmful might be introduced.
2. Permanent facilities will have to be provided for the breeding of these valuable insects, so that a stock will always be available for release in plantations where there is any invasion of noxious insects. For example, the fruit fly is a pest which it has recently been found possible to breed in the laboratory throughout the year on carrot pulp, experiments with various kinds of fruit having previously proved unsuccessful. As a result, the parasite of this fly, *Opius concolor*, can now also be bred and can be released in orchards as the need arises.
3. A thorough study must be made of the biology of the entomophagous insects it is proposed to use, one important point being to know whether climatic conditions in the area where they are to be let loose will be congenial to them and whether they will be able to adapt themselves to it. Shelters must be arranged where they can spend the winter months. In the Soviet Union, for instance, where certain species of lady-bird are used for biological control purposes, they are provided with refuges for the winter. Uncultivated areas will have to be left in the midst of plantations where

the entomophagous insects can breed. This need is clearly brought out by the methods used for the control of the olive fruit fly. In the old type of olive grove, such as exists in Crete, scrub is left between the olive trees and 80 per cent of the olive fruit flies are killed off by their parasites. No considerable damage is therefore to be feared. It is therefore advisable not to clear away the scrub from olive growing areas. 'Unfortunately, it is the fashion nowadays to combat the olive fruit fly with such chemical substances as parathion and other phosphoric esters. Until quite recently it was believed that the effectiveness of any products is in direct proportion to its toxic properties—a fallacy which is still doing much harm. Fortunately olive-growers are beginning to realize the effect of parasites on the fly pest. It is to be hoped that, armed with this knowledge, they will induce the administrative services to favour methods of biological control for the purpose of saving their wealth, which is also the wealth of the nation.' [1]

4. One last precaution! Care should be taken not to introduce with the useful insect any of its parasites which might keep down its numbers or even completely destroy it.

Valuable results have already been obtained. In addition to those already mentioned, reference should be made to the control of the white cabbage butterfly and of the dreaded San José scale, which is a very serious orchard pest. In the Heidelberg region of Germany 2,600,000 of its parasites were let loose over a three-year period and 40 to 70 per cent survived temperatures of –28° C, thus demonstrating the possibility of devising a satisfactory system of breeding entomophagous insects which effectively control orchard pests.

The use of ants provides another instructive example of this method. Under the leadership of Professor M. Pavan of the University of Pavia, thorough studies were conducted in Italy [2] where wooded areas are constantly increasing for a number of reasons, such as man's gradual drift away from mountain regions. Attention therefore had to be given to the protection of forests against insect pests. As insecticides proved ineffective, biological control by means of ants was tried out. It is estimated that red ants clear the Italian forests where they live of over 14,000 tons of insect pests a year. It was therefore worth while trying to acclimatize such diligent helpers. Spectacular results were obtained after several years' experimentation, the processionary caterpillar which attacks pine trees being completely eradicated. The ants used are most aggressive and, in some cases, have succeeded in wiping out colonies of termites. They attack the native ants ferociously. They also hold in check an insect harmful to the larch.

These few examples singled out from a long list illustrate the effectiveness of entomophagous insects when the necessary preliminary studies have been

1. C. A. Issaakides, 'Sur la Lutte Biologique contre le Dacus oleae', *Entomophaga*, 1957, pp. 245-9.
2. M. Pavan, *Attività italiana per la Lotta Biologica con Formiche del Gruppo* Formica rufa *contro gli Insetti dannosi alle Foreste*, Pavia, 1959.

carefully made. Biological control methods have yet another not inconsiderable advantage, namely, their inexpensiveness. Only a very small staff is needed to rear the insects once the right technique has been worked out.

USE OF MICROBES

Many microbes which take a heavy toll of insect life have been selected and successfully employed over the past few years.

Of the bacteria, *Bacillus thuringensis* has proved the most effective. It is now produced on an industrial scale for marketing. In France, it is produced by the Institut Pasteur, and its practical application has yielded conclusive results. The southern slope of Mont Ventoux in Provence is covered with a pine forest regularly infested by processionary caterpillars. In September 1957, the trees were treated with a suspension of *Bacillus thuringensis*. In the whole of the experimental area, no one living caterpillar was discovered one month later. Many other butterfly pests have been successfully controlled—the corn borer *(Pyrausta nubilalis)*, the white cabbage butterfly, etc. In the Soviet Union, suspensions of *Bacillus thuringensis* are used on a large scale in the Siberian forests; there the microbes seem to maintain their activity indefinitely, thus making repeated treatment unnecessary. In the United States of America another bacterium has been successfully used for the control of *Popillia japonica* or Japanese beetle, a very serious tree pest.

Viruses have also been selected for use. *Rickettsia* viruses destroy grubs, and processionary caterpillars are killed off in large numbers by polyhedral disease caused by another virus.

Many microscopic fungi have also been tried as means of combating both crop pests and the direct enemies of man. The Tokelau islands, a group of coral atolls in mid-Pacific, were the scene of a series of most promising experiments, organized by New Zealand and the World Health Organization. The object was to discover whether it is possible to communicate an infection to the mosquito which transmits filariasis, one of the causes of elephantiasis. The mosquitoes responsible were infected with a fungus from Malaya. The difficulty was to transport the fungus alive from its native habitat to the middle of the Pacific. In 1960, the results were studied. The larvae of the parasitic mosquitoes were prevented from reaching the adult stage and there was an almost 50 per cent drop in the adult insect population. It is therefore hoped that these mosquitoes can be completely wiped out within a few years.[1]

OTHER METHODS

An entirely novel method of abating the insect nuisance has been devised for the elimination of a particularly harmful cattle parasite, the screw-worm

1. *World Health*, May-June 1961, p. 12.

fly *(Callitroga hominivorax)*, which has caused much damage in the south-east of the United States. The larvae or maggots of this fly live under the skin of animals and are capable of causing extensive harm. They may even develop in man and have been known tocause death. The usual treatments with insecticides yielded no results. Entomologists and veterinary scientists working in the United States agricultural research services then began to rear millions of screw-worm flies, the pupae of which were subjected to intense cobalt 60 radiation. The tremendous resistance of the insects to radiation enables them to survive, but those which develop into adults are sterile. When set loose, the sterile males mating with normal females which have not undergone treatment prevent them from reproducing. The result is the complete extermination of the insect pest. In the past two years, not a single screw-worm has been detected in the south-east of the United States, but in the south-west, where there has been no eradication campaign, the damage caused by this fly is estimated at $25 million a year.

In the United States, research workers have directed their efforts towards the selection of plants that are resistant to insect attack. This resistance may have three causes. The plant may not be sought out by insects for egg-laying or for food; or the plant may have some effect on the biology of the insect (reduced vitality, lowered fertility); or the plant may withstand insect attacks. A score of species have been studied in the United States of America—barley, cotton, sugar-cane, potatoes, etc. Further research has been conducted in Argentina, Canada, France and other countries. For instance, it has been demonstrated that crossing of the potato with a wild species promotes the appearance in the leaves of a substance, demissin, which repels the Colorado beetle larvae and prevents them from feeding on the plant. The adult insects eating this hybrid potato have their fecundity reduced or are even rendered completely sterile. Improved methods of chemical analysis will lead to more reliable identification of the substances responsible for plant resistance and will speed up progress in this field.

In view of the outstanding and steady progress made in physics, many people are apt to show surprise or annoyance that biology, despite some spectacular successes, is limping behind. The fact is that living matter cannot be so readily controlled by man as inert matter. In the complex problem of pest control, there have admittedly been many failures and disappointments, but progress has nevertheless been substantial. At present, a method relying on both insecticides and biological control is being successfully applied to combat certain parasites such as the sunn pest in Iran. A tireless search for new means of control is being conducted in the laboratories. There can be no doubt that in time and with the necessary facilities biologists will succeed in solving a problem which is of critical importance for the future of mankind.

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